Popular Astronomy

Vol. LII, No. 9 NOVEMBER, 1944 Whole No. 519

Double Stars*

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Before attempting a description of this branch of astronomy for the past half-century, let us glance a moment at the position it held as this period began. Practically founded by Sir William Herschel about a century earlier, double-star measurements had been brought to considerable perfection by Struve who in 1837 published his classical "Mensurae Micrometricae." From then on until about 1870, when Burnham began his remarkable series of discoveries, its progress had been rather uneventful. Burnham's skill as an observer proved, contrary to current belief, that a vast number of doubles remained undiscovered and gave a fresh impetus to the subject so that it remains one of the most interesting in stellar astronomy. During the period mentioned up to 1889, all work was visual and practically all was done with the filar micrometer, though the double-image micrometer was known and the heliometer may have been occasionally employed. Meantime, the spectroscope was coming into more general use and being constantly improved, so that E. C. Pickering in 1889 was able to announce that the visual double, Mizar, was itself a binary, its character being betrayed by the periodic doubling of the lines in its spectrum. From this time on the discovery of the binary character of stars through study of their spectra, when the component stars are far too close angularly to be detected by any direct scrutiny, has been a most important branch of double-star astronomy. Hence, as our half-century begins we find astronomers furnished with a new and powerful means for the study and detection of double stars. Also in America, the Lick 36-inch refractor was shortly to be employed by Aitken[1] and Hussey in their epoch-making survey of the northern and part of the southern heavens, while the Yerkes Observatory, with its great 40-inch refractor, was about to be inaugurated. Here Burnham would continue his great work until his retirement in 1912, followed to the present most ably by Van Biesbroeck. Also, Innes in South Africa had begun a systematic campaign of measurement and discovery on the so far much neglected southern skies. Contemporaneously, excellent visual double-star work was being carried on at Greenwich and many continental observatories until 1914. In these same 20 years, double-star work has pushed at several other American observatories among which may be mentioned Dearborn, Flower, Lowell, and Leander McCormick. During the next few years,

*The seventh paper in the series of Astronomical Summaries.

the use of several of the larger refractors in America for photographic parallaxes furnished, as a by-product, large numbers of plates on which double stars appeared. Hundreds of measures of such doubles were made by Olivier[2] at McCormick Observatory and shorter lists by Pitman[3] at Sproul Observatory. In Europe, at Potsdam, Hertzsprung[4] was in the meantime devising a method, by use of a coarse refraction grating placed in front of the object glass, which made possible measures to a higher degree of accuracy than could be attained for images on the ordinary parallax plate. His very important results appeared in 1920. Also in 1920, at Mt. Wilson, J. A. Anderson[5] devised the double-star interferometer and successfully measured Capella. An orbit for this binary was worked out by P. W. Merrill[6] to a degree of accuracy never before attained, based upon more interferometer measures by him. In Italy, Maggini,[7] in 1923 and 1924, published a series of such measures of double stars. In 1936 and 1941, R. H. Wilson[8] at Flower Observatory also published two series of interferometer measures. In 1925, Pease at Mt. Wilson devised the beam interferometer and resolved Mizar, already notable as being the first spectroscopic binary discovered. At McCormick Observatory photographic double-star work, with added precautions and improvements, especially study of systematic error, was carried on by D. Reuyl.[9] K. Strand at Leiden carried on similar work, using the Hertzsprung grating method, and then coming to Sproul Observatory continued this work. Van de Kamp,[10] at Sproul, has recently exclusively used parallax plates for the determination of the masses of the components of double stars. Indeed, photography has so superceded visual work that for the last decade in America the 40-inch at Yerkes Observatory and the 18-inch refractor at Flower Observatory are almost the only large telescopes used much of the time for visual observations on double stars.

It would be quite unjust not to mention that, in the period from 1920 to the beginning of World War II, excellent double-star work was being done in Europe, much of it visual, but some photographic, and a little with the interferometer. French, Dutch, British, Russian, and other astronomers were all contributing long sets of measures and many were working on orbital or other theoretical problems concerned with this branch of astronomy.

However, a word of explanation should here be given. No matter how perfect the photographic image, the components of double stars which are less than 1″ apart can scarcely be separated on a plate, even when every other circumstance is favorable. Further, when one differs much from the other in brightness, and they are fairly close, photography may fail. Therefore, for the very close stars, among which binaries are most likely to be found, it is still to visual observations alone that we can turn. In general, there are difficulties for stars closer than 2″. For those cases, however, favorable for photography, the accuracy attainable is many times greater than for the best visual ob-

servation. The grating method is here referred to for components which differ in brightness; the measurements of images of doubles fortuitously found on the average parallax plate, for instance, are not measure for measure much superior to visual measures by the best observers.

If the telescope used does not have a long focal-length, the measures on the plates are generally inferior to visual measures as has been tested in the extensive lists of stars by Barton[11] which he has detected as double in the Astrographic Catalogues. Others who have worked with these same catalogues or other photographic plates taken with telescopes of short focal-length confirm his results.

With this very brief résumé, we turn to some of the details of work which were especially important. Double-star astronomy is particularly dependent for its progress on knowing what others have done so there shall be little needless duplication of effort. Except for Struve's great work, and a later (1874) comprehensive list of doubles by Sir John Herschel,[12] which, however, lacked the actual measures and so was not as valuable as it might have been, our epoch started without any up-to-date catalogue of doubles. For the northern hemisphere and to 31° south declination that want was filled by the publication in 1906 by Burnham of his "General Catalogue," in two parts. The first listed 13,665 double stars, including practically every object so designated in the area mentioned up to the time of publication. Part II contained measures, notes, orbits, references, etc., on the objects in Part I. This immediately became the standard reference book and was invaluable. Its principal defect was in not discarding many of the earlier Herschel and other objects which were very faint and wide, and most of which have no chance of being binaries. Even earlier, in 1899, R. T. A. Innes published his "Reference Catalogue of Southern Double Stars." This was not so ambitious a work as Burnham's, but nevertheless most valuable. In 1917, R. Jonckheere published a very useful catalogue covering discoveries to 105° N.P.D., for the epoch 1905 to 1916. He is to be congratulated in that he refused to list objects of greater than 5″ separation, which for fainter stars have so few chances for being true binaries. In 1927, Innes, assisted by B. H. Dawson and van den Bos, issued a loose-leaf catalogue covering southern doubles south of —19°. This too is an excellent and most useful work. In 1932 appeared Aitken's "New General Catalogue of Double Stars within 120° of the North Pole." The preparation of this work was first undertaken by Eric Doolittle but, on his death in 1920, the data were turned over to Aitken who enlarged it to include known discoveries to 1927. He also most wisely discarded large numbers of the very wide doubles of the earlier observers. Even then the catalogue contains 17,181 entries. It is so complete that it will remain the standard reference work for a long time. The four catalogues mentioned, which in all cases partly supplement or overlap one another in both areas and periods covered, give

a very complete picture of the subject up to 1927. Since then, the papers listing discoveries by various observers will have to be consulted if one wishes to bring his knowledge of known double stars up to date. This means having access to the publications of observatories and the leading journals dealing with astronomy.

Specific programs of discovery should next be reviewed. Burnham had, in 1870, started his career as a discoverer with a 6-inch refractor. Later he joined the staff of the Lick and then the Yerkes Observatory and was able to employ their great telescopes in his favorite work. His total discoveries numbered 1340, many of them very close and difficult objects. He never attempted a systematic survey. Aitken[1] began his survey of all B. D. stars of 9.0 magnitude or brighter in 1899, and a couple of months later was joined by Hussey, the two dividing the sky into zones for their respective searches. Using the superb 36-inch and 12-inch refractors at the Lick Observatory, where conditions are so excellent, this work netted about 4400 new pairs. Hussey, who resigned in 1905, found 1329, Aitken the rest. It is possible that, when both the number *and* importance of his discoveries are considered, Aitken will be the outstanding double-star astronomer of all time. Hussey, going to the southern hemisphere, continued his discoveries until his early death cut them short at a total of 1650 pairs. The special importance of the Aitken-Hussey survey was that it was systematic and among other results showed that, down to magnitude 9, one star in every 18 was a visual double.

The 27-inch Lamont refractor, designed by Hussey, was set up in South Africa and employed in discovery and measurement of doubles. Though he personally did not live to initiate the actual observing, the staff to whom this excellent telescope was intrusted has made outstanding contributions in new discoveries of southern double stars. These observers examined fainter stars than did Aitken, and Rossiter,[13] who has discovered the largest number, up to January, 1944, has announced 5179 new pairs. Several thousand more were found there by the others of the staff.

Innes has already been mentioned as the author of the two extensive catalogues of southern doubles, but his work as a discoverer was also most important. Beginning this work at Sydney, N.S.W., in 1895, he soon went to South Africa, joining the Staff of the Cape Observatory. In 1903 he was promoted to director of the Union Observatory, Johannesburg. In 1925, a fine 26½-inch refractor was installed there, and a systematic survey begun along the general lines of Aitken's in the northern sky. Innes discovered over 1600 doubles. His colleague, van den Bos,[14] has largely exceeded this number. On the erection of the Lamont telescope, coöperative work was arranged so that now the southern sky is, if anything, more systematically surveyed for doubles than the northern. Even more recently in Java at the Bosscha Observatory at Lembang, where a 24-inch refractor was installed in 1924,

double-star measurements formed a large part of the program. The past tense is advisedly employed as the writer has no information as to what has happened to either staff or equipment since the Japanese invasion. Knowing their record in other occupied territories one must fear the worst. This brief survey of discovery among southern stars should stop with mentioning outstanding work, beginning as early as 1912, by B. H. Dawson,[15] using the 17-inch refractor at La Plata Observatory, Argentine. While his total in discoveries is much smaller than those mentioned, the principal value of his work was in measuring great number of doubles, largely or wholly neglected at the time. He also coöperated with Innes in the preparation of the second catalogue, already mentioned.

Most double stars have been measured visually with the filar micrometer, and a certain percentage, more recently, on photographic plates and with the interferometer. In all cases the basic measurement is to obtain the polar coördinates of the fainter star with respect to the brighter. From these is derived obviously the apparent orbit of the former about the brighter. We find the orbits are ellipses. But by the law of graviation the center of attraction must be at a focus, while also, by geometry, an ellipse projects into an ellipse. What we see is the *projected* ellipse, and in this, foci do not project into foci, yet the law of areas still holds. Numerous methods for calculating the true from the apparent ellipse have been devised, some over a century ago. It is no part of this paper to go into mathematical details of these methods, but only some recent changes or improvements in approach. In *every case* it must be understood that, whether a graphical or analytical method be used, the attempt is to pass the best apparent ellipse through the actual observations. On the face of it, this does not seem a very difficult matter until one examines the data. First, though nearly all doubles are true binaries, the periods of most are so long that since accurate (or any!) observations are available they have traversed only a few degrees of their orbits. Omitting spectroscopic pairs, less than a hundred have been followed through a complete revolution, while only a few score have fairly accurate orbits. Also, many of those which have completed a revolution are very close pairs. Few observers would venture to say that the accidental plus systematic errors of a single night's observation were much less than $\pm 0''.1$. Yet most known orbits have their semi-major axes certainly less than $3''$, many less than $1''$. It can hence be seen what a large *per cent* $0''.1$ is of either of these quantities. The wider binaries may take thousands of years before they, as a class, permit calculation of their orbits. This very brief explanation indicates first why we have so few orbits, secondly, why the elements of those we do have are not more accurate in per cent. Of recent methods for calculating orbits, the Thiele-Innes[16] method and the Henroteau-Stewart[17] method may be mentioned. The paper by Thiele actually appeared in 1883, but Innes and van den Bos (1926 and

1932) revived and improved it. It depends upon forming three normal places and then finding the value of C, the double areal constant. The so-called Thiele-Innes constants that are derived from this method can easily be turned into the usual orbital elements by simple trigonometrical transformations. The Henroteau-Stewart method is more largely a graphical one, and should be very useful in certain cases.

The value of double stars in sidereal astronomy comes from a variety of causes. First, if we include spectroscopic binaries, perhaps one star of every three is a double. Therefore, in studying them as a class we concentrate upon a path of evolution followed not merely by exceptional objects but by a large per cent of the whole stellar population. Further, we must derive the mass of a star by its attraction on another: binaries furnish our only available cases. It is obvious that mass is one of the most important of all data and of fundamental interest. But when Eddington[18] announced in 1924 the totally unexpected mass-luminosity relation, accurate masses were the basis of his curve on which all his results depended. The basic data could come from nowhere but double-star orbits.

In elementary astronomy the following equation is derived:

$$m_1 + m_2 = a^3/p^3\,P^2$$

in which, for a binary, m_1 and m_2 are the respective masses, in terms of the Sun's mass as unity, a the semi-major axis of the orbit in seconds of arc, p the parallax of the system in seconds of arc, and P the period in years. It is hence seen that when an accurate orbit *and* parallax are available the *sum* of the masses of the components can be derived. Only in the last 30 years have accurate parallaxes been available in any number. But some of the binaries, which have good orbits, are so distant that the probable errors of their parallaxes equal or exceed the derived parallax. This in turn means most uncertain masses. Little can be done about this as there seems small chance of appreciable improvement in the accuracy of parallax measurements by direct methods. In such cases, however, spectroscopic parallaxes should be used, if available. It is just one more of the difficulties we face in attempting to study the stars, most of which are so very, very far away that our base line of 186,000,000 miles is far too small to serve.

Spectroscopic binaries have barely been mentioned. By the Doppler principle, if an object is coming toward us, the lines are shifted toward the violet of their normal position, if receding they are shifted toward the red. In both cases the shift is proportional to the velocity. The average star will therefore have a shift which remains constant. But a binary, in addition to the constant velocity of the center of gravity of the system, toward or from us, will show additional shifts due to the actual orbital motion of the two components. Methods have been worked out for the solution of such orbits, the elements being in part different from those of visual binaries. Three, however, are the same

in both classes: namely, eccentricity, period, and epoch. Of the others we are here interested only in the major axis. For spectroscopic binaries we cannot find the semi-major axis, but do find $a \sin i$ where i is the orbit's angle of inclination to the background of the sky. It is obvious that $a \sin i$ is less than a always, hence only a minimum value can be obtained. Where spectroscopic observations can be made on components of visual binaries so that both types of data are available, the double sign, present in the visual orbit, before i can be omitted, and we know whether i is actually $+$ or $-$.

For spectroscopic binaries, unless additional data are at hand, when their orbits are solved the results as to masses fall into two categories. The first, where lines from the spectrum of each component are visible, furnishes the following values: $m_1 \sin^3 i$ and $m_2 \sin^3 i$. As $\sin^3 i < 1$ always, these are the minimum values m_1 and m_2 can have. In practically every case except for eclipsing binaries they are considerably greater therefore. The second case, when only one spectrum is visible, that of the other component being too faint to photograph with the power available, we find what is known as the mass function

$$f = \sin^3 i \, [m_2^3/(m_1 + m_2)^2].$$

This again gives a value which is perforce smaller than the true masses. While for any given spectroscopic binary the masses are therefore unknown, for large numbers an average value can be calculated, and so, statistically, such masses can be used in many investigations. "The Third Catalogue of Spectroscopic Binaries," issued from the Lick Observatory in 1924, contains 1024 objects. Since then large numbers have been added. Progress here depends upon more powerful instruments and faster photographic plates, because so far most of these objects are among the brighter stars. This is not because there is not an equally large percentage of spectroscopic binaries among fainter stars, but because of the almost prohibitive lengths of exposures necessary, even with great telescopes, to secure measurable spectra of sufficient dispersion to detect the velocity changes. This is a field in which the largest reflectors have a great advantage over any existing refractor. It is one which has been almost wholly developed in the past half-century under review.

Measurement of doubles by the interferometer, mentioned before, have been made in past quarter-century only. The beam type of interferometer is cumbersome and expensive, and needs a large telescope for its use. While of great value in the measurement of the diameter of stars, the simpler type is the one usually employed for double stars. With the latter, in the hands of a skilled observer, the resolving power of a telescope is about doubled, and, what is perhaps even more important at most observatories where excellent seeing is certainly not the rule, measurements are still quite possible on nights of fair or even poor seeing. The available nights for double-star work

are hence greatly increased in number and the value of the results, due to the fact that only close doubles are proper objects for the interferometer, is increased. The standard types of instruments, developed and used at Mt. Wilson, have been described in great detail. Here mention will be made only of the construction of the one at Flower Observatory, by R. H. Wilson,[8] which he attached to the 18-inch refractor and used with much success. This consisted of a tube fitting into the filar micrometer and extending 56 cm inside the telescope, its inside diameter being 5.25 cm. At the upper end were placed the slits. These were cut into stiff, blackened paper, and were symmetrical sections of a planoconvex lens, with the chords nearer and parallel to one another. Actually, five different pairs of slits were used according to circumstances.

With this device stars as faint as of the sixth magnitude could be observed, but the components cannot differ by more than two magnitudes. The reason that stars below the sixth magnitude could not be measured is that their interference fringes are too faint. Even for brighter stars the fringes are none too easy to work with and the observations are extremely trying on the eyes. Atmospheric irregularities at low altitudes and changeable seeing tend to imitate the effect on which observations depend. Hence, higher altitudes should be used if possible. At best, a certain small unpredictable percentage of the results turn out illusory or incorrect. Yet the vast majority are in excellent agreement with micrometrical measurements, when these are available for comparison. The method has therefore to be used with caution, and is obviously available only for brighter stars, no matter what telescope is employed. It is, however, a very powerful one and has added valuable information on many stars when their components were far too close for measurement by smaller instruments and very difficult for the larger. Measures with the interferometer had been made also in recent years by Danjon at Strasbourg Observatory and van den Bos and Finsen at Union Observatory,[14] Johannesburg.

An interesting combination of spectroscopic and parallax data was independently conceived by several persons, certainly before 1915. However, it has been most extensively and successfully applied by H. L. Alden, director of the Yale Observatory branch at Johannesberg. The plates used were those taken at McCormick Observatory and, later, others at his present station. The most important of the several cases he has solved is that of χ Draconis,[19] which has both a large parallax and a large $a \sin i$ for its spectroscopic orbit. It is also near the pole of the ecliptic, which gives it a large parallax in declination as well as right ascension. Good elements for the true orbit were obtained for this star, and the method is applicable to any spectroscopic binary which is not too distant.

Hertzsprung's Method. This astronomer,[4] while working at the Potsdam Observatory in the years 1914 to 1919 inclusive, developed a

means for obtaining photographic measures of double stars with components not of equal brightness, which greatly exceeded former ones in accuracy. This is achieved by placing before the object glass of a visual refractor an objective grating. In practice he used the 50 cm refractor, and a variety of gratings. These latter differed in the diameter of the coarse wires used and how far they were spaced. The wires must be parallel. When a star is photographed using such a grating, one secures a large, relatively bright central image of the principal star, with secondary images spaced symmetrically to right and left. If the line through these is made, by rotation of the grating, to be approximately perpendicular to the line joining the primary star to its companion, then the rectangular coördinates of a symmetrical pair of the secondary images divided by 2 give the coördinates of the primary star. The companion's image is directly measured and its secondary images, if indeed they show up, are ignored. From these coördinates clearly the position angle and distance of the companion can at once be computed.

Hertzsprung's telescope had a scale of 16″.39 per mm, and he used yellow-green sensitive plates, both with and without color screens. Ordinary plates, due to atmospheric dispersion, can displace red stars relative to blue ones. For instance at $Z = 45°$, there is a shift of 0″.18 for a K star relative to an A star. With his special plates this type of error was practically eliminated. By choosing a grating, suitable for a given double, he could make the primary's secondary images almost equal to the companion's image. This eliminates the extremely troublesome "magnitude error," which parallax observers try to avoid by using the rotating sector. Very large numbers of exposures were obtained on the same plate, sometimes extending to over a hundred. Exposure times varied according to circumstances, but were practically all limited to less than one minute. From this array, only the better images were chosen for measurement, those distorted by guiding error or poorer seeing being omitted. In the publication referred to, we find the work fully described. The results were on 126 Struve stars, for which 408 plates with 16680 images (4520 with objective grating) were taken. They are given to the hundredth of a degree in angle and to the thousandth of a second of arc. However, despite all the precautions taken, the average probable error is of the order of ±0°.1 and ±0″.01. Nevertheless, this paper shows about the limit of accuracy now obtainable. It should be added that the minimum distance of any of the 126 pairs was 1″.2, many were much wider. His most interesting single result was detecting and actually measuring the suspected secondary period of 1.8 years in the well-known binary ξ Ursae Majoris.

Of great significance is the publication, in 1937, by K. Strand of work done by him at Leiden Observatory,[20] where Hertzsprung was then director. The general methods followed were essentially those just outlined, but the data came from plates taken at Potsdam with the 50 cm refractor and at Johannesburg with the 67 cm refractor, the scale of the

latter being 1 mm = 18″.91. The stars investigated were the six famous binaries; η Cassiopeiae, γ Virginis, ξ Bootis, 44 i Bootis, σ Coronae Borealis, and 70 Ophiuchi. He measured an average of 55 images per plate, but states that this number varied from 16 to 217 as extremes. As Hertzsprung made 60,806 and Strand made 63,310 single settings in the measures on which the results are based, it was possible to see whether there was any systematic difference between the two measurers. This was 0″.009. A so-called plate error, varying from plate to plate was found: this was ± 0″.008. A careful study was made, using available photographic and visual measures of a larger selected list of doubles, to find systematic differences. Using Hertzsprung's results, discussed already, it was found

$$d_{ph} < 3''.0,\ d_{ph} - d_{vis} = -0''.057 \pm 0''.010 \text{ for } 27 \text{ doubles}$$
$$3''.0 < d_{ph} < 4''.0,\ d_{ph} - d_{vis} = -0''.007 \pm 0''.010 \text{ for } 18 \text{ doubles}$$

From plates with the Leiden refractor (33 cm aperture, 524 cm focal length), he finds

$$d_{ph} < 6'',\ d_{ph} - d_{vis} = -0''.075 \pm 0''.024 \text{ for } 26 \text{ doubles}$$
$$d_{ph} > 6'',\ d_{ph} - d_{vis} = +0''.007 \pm 0''.014$$

It would seem then, when the larger telescope is used, that there is no systematic difference for a distance $> 3''$, and when the smaller telescope is used, for $> 6''$. Pairs with approximately equal components are discussed here.

For the actual calculation of the orbits, Strand used all observations, visual and photographic, from 1830 on, except some few of the former which gave abnormal residuals. This is scarcely the place to go into fuller details of his computations but the paper in which they appear is so full, the steps so clear, and the final results so accurate, that it seems difficult to improve upon the orbits there derived. In general he concluded that "although the photographic measures yield almost one decimal more than the visual observations, no deviation from Keplerian motion was found in any of the systems." Further, that no systematic error in position angle, in any of these systems, was found between visual and photographic measures, and this was also true in distances for 44i Bootis, ξ Bootis, and σ Coronae Borealis. For η Cassiopeiae visual distances averaged 0″.039 ± 0″.008 smaller than photographic. For γ Virginis visual distances were too large by 0″.044 since 1878. For 70 Ophiuchi visual distances below 2″.5 separation were too large; for the rest of the orbit, too small. Noting the difference given it is clear that, up to date, even the best photographic distance is not *certain* to less than 0″.01 and no combination of visual measures to less than perhaps 0″.04. After all, however, the first quantity is an angular accuracy of 1 part in 20 million!

By study of the proper motions of Sirius and Procyon it was found a century ago that these stars followed a wavy curve rather than a straight line. In both cases the presence of a companion was predicted,

and these latter were eventually discovered visually. Their periods turned out to be 50 and 39 years, respectively. Though the two bright stars perforce cannot thus follow straight line (or more correctly, great-circle) courses due to their proper motion, yet the center of mass of each system must do so. It would seem obvious then that all one would have to do is to observe carefully the proper motion of any star and, if it deviated from a straight line in a periodic curve, the star must be a binary. Next, of course, the companion would be sought for by all available means in hopes of detecting it. The above statement is true enough, but alas, for its practical application, the stars are so terribly distant that up to date not many show the slightest deviations from straight-line proper motion. Yet a few not already known to be binaries have done so, thanks to the remarkable accuracy of measurements attained on plates taken to determine stellar parallaxes. When the star is already known as a binary, the deviation of the center of mass from its expected straight-line path indicates the presence of a third body, hence, that the star is really a triple, not merely double. D. Reuyl[21] in 1938 announced the variable motion of Ross 614. K Strand[22] in 1943 proved that the well-known systems, μ Draconis, ξ Bootis, and 61 Cygni, each shows perturbations by a third and invisible component. His former work at Leiden is thus amended in the case of ξ Bootis, additional plates taken in 1939-42 with the Sproul Observatory 24-inch refractor being the deciding factor. It will be of interest to quote here his derived masses, in terms of the Sun's mass, for the components of the three above systems, in order: 1.5, 1.5, 0.6; 0.8, 0.8, 0.1; and 0.58, 0.55, 0.016.

Work of this nature has been most successfully prosecuted at Sproul Observatory by van de Kamp, its director, but as the whole subject was fully discussed by him in the April, 1943, number of this periodical, it is needless to pursue the subject further here. Again in April, 1944, the same author published the paper in this anniversary series "Astrometry and Astromechanics" where he thoroughly dealt with the theoretical basis of double and multiple star research.

In conclusion, it must be confessed that ideas or theories on the evolution of binary or multiple systems are in the same state of confusion that, at present, besets all evolutionary theories. It is like a picture puzzle in which we have many of the pieces but so far it has proved impossible to put them all in their proper places so that a result is attained, generally acceptable to astronomers. Very briefly, the two most prominent theories are those of evolution from separate nuclei in a primordial nebula, or fission from centrifugal or other force after the original star has been formed, whose pieces must become the two or more components of our system. Persons who are interested in this phase of our subject should consult numerous articles written in recent years by leading authorities. A few references will be given in which this subject may be studied further.[23]

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FLOWER OBSERVATORY, UPPER DARBY, PA., 1944 SEPT. 11.

Record of Sun-Spots and Faculae*

By H. B. RUMRILL

The following recital of solar observations, representing the work of the Rev. A. W. Quimby and of the writer, successively, during a period of fifty-five years, is offered as a contribution to the study of periodicity.

My interest in the study of the Sun grew originally out of reading Langley's "The New Astronomy" some years before I possessed a telescope with which to examine its surface. It was while living in Bryn Mawr in 1906 that I received a four-inch object glass from the John A. Brashear Company, Pittsburgh, together with some necessary parts, including a universal equatorial head, for mounting it, which I undertook because of wishing to embody certain ideas of my own, particularly a strongly braced tripod of more than usual weight for a portable instrument. The mounting in its entirety, however, turned out to be much too heavy for readily carrying in and out of doors, and when so used I generally omitted the parts made for strengthening the tripod. Even without these it became rather burdensome to handle, leading to the making of observations through a south window, upon removal to

*Covering the period of 55 years beginning July 1, 1889.

Berwyn a few years after.

Thus situated (with the tripod widely spread and the polar axis lowered, due to inadequate window height) the employment of this telescope for solar study was for a number of years confined to the fall and winter, from late in September until late in March, when I could view the Sun during the early morning hours. In the spring and summer several small telescopes were substituted in counting the spots and faculae. Of these, an old one made by Cary, London, having an aperture of 2 inches, served well because of excellent definition, although afterward others of about the same aperture, but greater focal length, suited the purpose better with their increased magnifying power. Occasionally these telescopes enabled continuity of observations while away from home.

Later on, having secured a good 3-inch object glass by Mogey, it was fitted in a square wooden tube on an old brass "pillar-and-claw" alt-azimuth stand made by Plössl, of Vienna, for a "dialyte." This stand has slow motions and is sufficiently steady for low powers, the aperture being quite enough for visualizing all but the faintest spots, wherein the 4-inch shows its superiority. Now that the larger instrument is located in a small observatory, the 3-inch is mostly used occasionally during the winter, especially at times when the dome is covered with snow. As a matter of fact, however, this condition has caused but little trouble.

The 4-inch object glass has been in service for nearly forty years, and has proven exceptional, of superb defining power, with any lack of achromatism scarcely noticeable. I remember Doctor Brashear assuring me that his object glasses of that aperture were equal in grasp to others of sizes up to 4½ inches, and my experience with those above 4 inches has not lessened my opinion of the telescope I have worked with so long.

Because of preoccupation with business cares, particularly for some years when frequently engaged in a traveling capacity, it was impossible to make closely consecutive observations of the Sun, so that the work suffered in a measure, but was resumed more fully with partial release from such duties. Regardless of this disability, every observation was duly recorded and drawings kept for any value they might have. It was only during the later years of this visual study of the Sun that systematic drawings have been made. Graphite pencils of the finest obtainable quality were at first used for these sketches, but a few years ago were discarded for the carbon pencils manufactured by Conté, Paris, until those of Wolff, London, were found preferable for the purpose, reproducing faithfully the contrasting blackness of the spot umbrae.

Trial of various kinds of paper finally led to the selection of Whiting's "Linen Ledger" of a thickness (.006 inch) represented by a weight of 36 pounds to the ream of size 17 x 22. This is cut to the standard

commercial size of 8½ x 11, permitting a diameter of 8 inches for the solar disc, large enough for exhibiting the least details visible. It is essential that the paper have a smooth, non-reflective surface, free from the specks and blemishes often present in cheaper stock. Each drawing gives the date, the hour (mean solar time), type of helioscope employed, the magnifying power, and the character of the definition, with any incidental notes.

A yellow pencil is used for showing the faculae—this after testing other colors, as amply distinctive. I have found that yellow affords a better contrast on white paper than white pencil on buff paper.

In general my drawings are made with the help of a helioscope having a wedge prism, on the Herschel principle, as manufactured by Brashear. It is the most convenient because the drawing board may be held at right angles to the prism box (out of the way of the beam of light—and heat—rejected by the face of the prism opposite its reflecting side), avoiding the impediment of the Sun's glare when looking directly as in other kinds of helioscope. The observatory is equipped also with a polarizing helioscope of the Merz form, by Brashear, and a Dawes eyepiece made by Cooke & Son, York, England. This latter is an admirable specimen of precision workmanship, having six single lenses of progressive powers and seven "London Smoke" glasses of graded absorption, each set mounted near the circumference of a wheel centered over an aperture wheel with ten accurately bored holes, of diameters scaled from 1/130-inch to 9/32-inch, the focus adjustable by rack and pinion. The reaming of these holes with a perfectly smooth edge is a matter of difficulty, as the writer learned when making a simpler device of the same sort with a nickel-silver disc and one high power single lens. The wheel of dark glasses has one open space, permitting the use of the eyepiece for other purposes.

Absorption screens of varied colors and densities (including the spectral colors first produced by Zeiss thirty-five years ago), with optically true surfaces, are used from time to time, while a Zeiss sliding wedge of neutral tint, fitted to a 20 mm "orthoscopic" ocular, has been found of general utility.

Throughout the years when there was opportunity to keep up regular observations, a record has been maintained similar to that of my predecessor, the Rev. Dr. Alden W. Quimby (reported by him semi-annually to the *Astronomical Journal* and to the *Polytechnium,* Zurich, Switzerland), showing the date, time of day, number of new groups, totals of groups and spots, number of faculae groups, and the character of the definition. Usually the latter has been expressed as "good," "fair," or "poor," but in continuing Doctor Quimby's work the writer has sometimes used such adjectives as "bad," "excellent," or "exquisite," in attemepting closer description.

On account of weather conditions, the winter record necessarily contains fewer dates of solar visibility than through the rest of the year,

and there are occasions when the Sun is not visible, except momentarily, in this section for as long as a week at a time. Intervals of two or three days are not infrequent, and often enough a single day intervenes between observations.

My observatory ("Tredyffrin Observatory," named from the township, following the precedent set by David Rittenhouse in naming "Norriton Observatory," built before the transit of Venus in 1769) is located in the highest part of Berwyn, some miles distant from the hills of Valley Forge, on the other side of the Chester Valley, at an altitude of about 550 feet above sea level. It is nearly eighteen miles from the center of the city of Philadelphia, very little affected by its atmospheric impurities, and hardly disturbed by the aura of artificial light that is such an astronomical detriment in urban localities. The latitude and longitude of the observatory are, approximately,—

Latitude, 40° 3′
Longitude, 75° 27′

As a rule the solar definition here is good, often so fine as to be beyond praise, evidenced by the visibility of spots so minute as to suffer disappearance with even slight diminution in the quality of the "seeing." As a consequence of what might be called "plus-minus" definition, the maintenance of a perfectly consistent record is impossible, although I am convinced that commonly only the smallest spots have been missed from this cause. Similarly, while the *number* of spots perceptible with either the 3-inch or the 4-inch aperture is generally more than with a smaller glass having lower magnifying power, the difference represents only the spots of least magnitude, although when these predominate the disparity is greater. Where small spots are very near together the increased separating power of the 4-inch is manifested in the counting as compared with lesser apertures. The principal requisite is the quality of the object glass; first-rate optical surfaces, such as distinguish those of Brashear, bringing out all the visual details of spots and faculae.

Of commensurate importance is the proper adaptation of the density of the dark glass to the solar light, minutae being easily overlooked when the latter is either too brilliant or insufficient, itself subject to some extent to the varying powers of eyepieces. This is wherein the polarizing helioscope has the advantage, with its perfect control of light value, while the Dawes eyepiece often gives a good account of its possibilities in critical study. The writer finds it to perform best in conjunction with the Herschel helioscope. The intricate structure of a huge spot group may be better comprehended where, as in the Dawes combination, there is facility in altering breadth of field, shade glass absorption, and magnifying power.

Regarding the Rev. Dr. Quimby's observations it would be difficult to speak too highly. Beginning his sun-spot record July 1, 1889, with a natural aptitude for the work, he devoted what leisure time he had

from ministerial duties to this self-imposed avocation. At first, while living in Philadelphia, he made use of a 3-inch telescope and about two years later came into possession of a very good 4½-inch object glass, mounted equatorially, with which he continued observing until incapacitated by the illness from which he died. It was early in the year 1922 when he relinquished solar observations and requested his friend, the writer, to "carry on." Although the latter was still so circumstanced as to be unable to yield the time required for the maintenance of an unbroken record, every effort was made to do so, but not so successfully as Dr. Quimby had accomplished, until the cessation of business activities provided additional opportunity.

In going over Dr. Quimby's lists as published in the *Astronomical Journal,* his assiduous application was at once apparent. In the light of the experience gained in the continuation of his program, and from comparison with my own endeavors, it was obvious that the only breaks in Dr. Quimby's competent studies were when the Sun was hidden throughout the missing days. Not rarely my observations have been made during a chance few minutes of visibility when clouds prevailed, as, in order to have such a record as complete as possible, one must watch for favorable occasions.

My recollection of Dr. Quimby is that he was gifted with discriminating sight, as witness the number of spots counted at many of his observations, sometimes exceeding 300, including faint spots that might have been beyond the reach of ordinary vision or of object glasses of inferior defining quality. That mostly used by him came from the firm of James W. Queen and Company, Philadelphia, along with a universal equatorial mounting on a tripod. The object glass was understood to have been made by Bardou, Paris, and the writer recalls, that, when reconstructing the telescope a number of years ago, its performance was excellent.

Having no observatory, it served wholly as a portable instrument. It was Dr. Quimby's custom to make observations from any available window in the parsonage at Berwyn, and whatever may be thought of certain impromptu appliances he depended upon, it is only fair to say that he had acquired uncommon skill in handling telescopes. His was eminently an instance of the importance of the "man at the eye end." The number of observations made by him assuredly attested fidelity to purpose, aggregating 10,882 during the period of 32½ years from July 1, 1889, to December 31, 1921, or an average of 335 yearly, the highest being 352 in the year 1908. So far as I know, this record excels in perseverance that of any other solar observer in its way, including the renowned Schwabe (a century ago), and Dr. Quimby once confided to me his earnest desire to aid in the determination of some secondary law or laws of periodicity.

Rev. Alden Walker Quimby was born May 6, 1854, at Womelsdorf, Pennsylvania. He received the degree of Master of Arts at Dickinson

College, which in September, 1921, conferred on him that of Doctor of Science. His activities as a clergyman included the Methodist Episcopal churches at Bainbridge, Landenberg, Charlestown, and Radnor, and his pastorate at Berwyn was said to be the longest in the history of the Conference, a period of 26 years. An original member of the American Astronomical Society, he was well known in the profession, and frequently gave popular lectures on Astronomy. He wrote in scholarly style, was an accurate historian of colonial events, and author of "Valley Forge," a romantic tale of the Revolution. His passing occurred at Berwyn on September 23, 1922.

In reducing the observations to the Wolf "Relative Sun-spot Numbers," based on the coefficient of 1 for a 3-inch telescope, the writer has chosen, as empirically, the fractional coefficients of ⅔ for 4½-inch, and ¾ for 4-inch telescopes, and corresponding coefficients for lesser apertures such as those of 2 inches and 2½ inches—having regard for the quality of the lenses and the factor of "personal equation"—applying these to the Wolf formula of ten times the number of groups and isolated spots, plus the total number of spots. Bearing in mind the somewhat arbitrary elements of the formula, especially when extended to a representation of other apertures than 3-inch, it occurred to the writer to prepare a series of summaries and graphs based on the principle of monthly and yearly *averages* of the numbers, the divisor being the number of observing days in each such period.

This treatment of the statistical basis proposed by Wolf assumes that at the times the Sun cannot be seen there will ordinarily happen no great changes in the spot relationships as recorded on contiguous observing days, provided the blind periods are short, *i.e.*, not more than a day or two. Where such periods are longer the method is not equally tenable, but any discrepancies may be considered as lost in the monthly and yearly averages. The artificial nature of the Wolf system itself seems to favor this method of illustrating the fluctuations in the numbers of groups and spots, and it has the merit of smoothing over the inevitable gaps of non-observing days and of days when no spots are visible. The conclusions thus arrived at appear to be reasonably consistent, and, while graphs so drawn can not of course reflect changes from day to day, they give a broad picture of spot evolution, through the cycles, that may not be far from truthful delineation.

Regardless of aperture, with determinate limits, the finest definition often brings into view many minor spots that disappear when the "seeing" deteriorates. It is remarkable how sharply diminutive spots stand out when the Earth's atmosphere is temporarily steady in one's vicinity, also how, when that of the Sun seems to be quiescent, the spot details are more easily visible—as if some obstruction had been removed —while on the rare occasions when both are concurrently tranquil the views obtainable are magnificent beyond description. I believe that the spot counting is affected less by slight differences of aperture than be-

cause of atmospheric limitations, and as between object glasses of 2 to 4½ inches, of highest grade, the smaller lenses miss only the minuter features to the practiced eye.

As to feasible magnifying powers, the solar definition in this neighborhood will seldom allow a greater amplification than, say, 200 diameters, and in my own experience a power half that much, or possibly up to 150—about 40 to the inch with apertures of 4 or 4½ inches—suffices. Specialized eye training is equally consequential, and I usually find that a lower power, such as a Zeiss "orthoscopic" of 20 mm (magnifying about 75 with 60-inch focal length, having a field embracing the entire disc of the Sun) is capable of disclosing most of the important details. Needless to say, the quality of the eyepiece supplements that of the object glass.

With the option of observing at any time of day, my personal preference has long favored early morning work, because of better "seeing" before the atmosphere becomes disturbed, although late afternoon definition often rivals that of the morning. There are many diversities, however, in the character of the "seeing" through the day, as at night, due in part to seasonal conditions as well as the local state of the atmosphere.

A description of my telescope stand may not be out of place. As first put together for portable use, the tripod legs were not substantial enough for the firmness essential to ideal performance and were shortly replaced by stouter ones, of solid mahogany, 2¼ x 3½ inches at top, tapering near the bottom to 2¼ x 2½. As erected in the observatory, and improved from time to time, the stand has given complete satisfaction, with little or no tremor when the telescope is properly balanced in both co-ordinates, even with high magnification. It rests on a concrete pillar built rather deeper than four feet in the ground, down to a bed of shale. The upper surface is 2½ feet square and has three equidistant hemispherical depressions, formed when the concrete was in a plastic state, to fit the curvature of steel balls of one inch diameter, fixed in the bottom of a wooden platform, the top of which was similarly drilled to receive a triangular base on which the tripod rests, and which was originally made for use along side a window. (The platform, 4½ inches thick, was superimposed for the purpose of raising the stand in order to command a lower altitude, the initial construction having been intended for a larger telescope.) The steel balls are placed over discs of lead, and in the case of the triangular base they lie in the prolongation of the centers of the tripod legs, their utility being the positioning of the equatorial head as exactly as practicable. The triangle brings the tripod legs close together, at an angle of about 80°, the general appearance similar to the Zeiss pyramidal stands, but so designed before my acquaintance with them.

The legs of the tripod terminate in conical bearings machined at the end of steel bolts having the standard screw thread known as "one inch-8," or eight threads to the inch, which enter deep into the legs

through bronze plates screwed thereto. These bearings, of angle 60°, rest in bronze blocks with beveled holes to correspond. A quarter-inch hole was bored through the lower end of each bolt, which by means of a steel rod as a key provides for the vertical adjustment of the tripod in order to bring the head horizontal as well as aid in the accurate setting of the polar axis.

The base of the equatorial head is fastened to the top of a heavy brass sub-base, into which it is recessed, and which may be turned on a "boss" fitting into the tripod head proper, as an azimuth adjustment, for getting the polar axis into true meridional position, being clamped by a nut at the end of a steel bolt passing vertically through the tripod head. The latter terminates in a projection threaded to fit a heavy 3-inch brass tube 18 inches long, into the bottom of which is similarly screwed a phosphor-bronze bushing having a shoulder on which rests a cast-iron cylinder tapped to hold the inner ends of three steel bolts, also of size one inch-8, centered through the tripod legs and held by knurled brass nuts on each side—this device greatly reinforcing the tripod and preventing any tendency to flexure. The whole contrivance adds considerably to the weight of the stand, which is thus centralized. Lower down three staunch brackets were affixed inside the tripod legs, on which rests a heavy iron casting of triangular form, having a central hole tapped to fit a standard one-inch bolt, over which are placed two heavy circular castings. Between the three castings are circular sheets of lead one-eighth inch thick, and the whole is fastened top and bottom with thick brass washers and case-hardened nuts. The addition of this lower central weight (about two hundred pounds) stabilizes the stand materially, the function of the lead being the absorption of tremors. None of the vibrations inseparable from the passage of trains over the tracks about 200 yards distant affects the image in the eyepiece, and the same may be asserted relative to the motor traffic moving along the highway some 50 yards from the observatory. It would, however, appear that primarily the shale formation and the clay overlying it do not transmit vibrations as in the case of solid rock strata.

While the above described mounting is no doubt inferior to an iron column as regards rigidity, it has been developed gradually through a number of years in attempting the solution of problems presented in the use of the telescope, and possibly affords some advantage of its own, although it has turned out to be a more expensive construction. It answers its purpose well, though, and has made observing a pleasurable occupation.

Thus far, the entire series of observations covers 55 years, or approximately five cycles reckoned from minimum to minimum, including that of 1944. It might be stated, incidentally, that some treatises on Astronomy make reference to periods when sun-spots are absent as sometimes consisting of several weeks. This does not state the case precisely. The register maintained by Dr. Quimby and the writer shows much longer

periods, those extending over a month or more being thirty during the minima of the five cycles. Twenty-three of these were about six weeks or more in length, of which thirteen covered at last eight or nine weeks each, the longest being thirteen weeks between April 8 and July 8, 1913, with 4½-inch telescope, there having been 313 days in that year when no spots were detected.

The approach toward the minimum phase is more gradual than that toward maximum; thus, during the four years 1892-5 there were no days without spots (except possibly days when unfavorable weather prevented observation). Then, during the succeeding years 1896-1904 the numbers of days without spots were 6, 32, 56, 136, 178, 288, 252, 74, 5. Although the record of the lengthy maximum between 1936-1940, during which the number of observing days was about 70% (as against 90% during 1892-5), contained no days without spots, it is probable—judging from the entirety of the 55-year account—that few, if any, days were minus spots.

The present minimum was approached during 1941-2-3 (with about 84% of observing days) by 32, 46, 91 days, respectively, without spots. During the first half of 1944 there have been 115 days without spots, out of a total of 145 observing days (about 80%), with the decided probability that the number of days lacking spots would have been increased to 145 if unfavorable weather had not caused more or less scattered non-observing days during the periods of absentia. Spots were recorded on only 30 days in the six-months period, but were doubtless existent on 5 or 6 additional (non-observing) days, or a total of nearly 20%.

At the close of this article are summaries of the numbers of observing days per year and of days without spots, also observing day averages—monthly and yearly.

The peaks of the *yearly* averages of the Wolf numbers were:

1892.....75
1893.....75
1894.....74
1905.....45
1917.....66
1928.....93
1937.....86

The peaks of the *monthly* averages were:

1893—August . . ..114,, total 3,544—31 observing days
1905—November . . . . 66, total 1,987—30 observing days
1917—August . . . .123, total 3,811—31 observing days
1928—July . . . .128, total 3,189—25 observing days
1938—July . . . .120, total 2,529—21 observing days

During the fourth and fifth periods other high points reached were:

Fourth period
1927—April . . ..105, total 2,003—19 observing days
1928—May . . . .100, total 2,006—20 observing days
—June . . ..115, total 2,296—20 observing days
—August . . . .102, total 1,624—16 observing days
—September . . ..118, total 1,889—16 observing days

Fifth period:
1937—February . . . . . 104, total 2,295—22 observing days
—April . . . . . 119, total 2,608—22 observing days
—July . . . . . 104, total 2,498—24 observing days
1939—May . . . . . 96, total 2,596—27 observing days

Variations in the length of the cycles are clearly exhibited in the summary of yearly averages of the Wolf numbers, the arrangement in sequences of eleven years contributing to this end. The low points of the yearly averages are not far from eleven years apart, with the exception that the first extends over thirteen years, as is the case with the maximum of 1892 to that of 1905. In the maximum of 1892-3-4 the highest monthly average was 114 in August, 1893, followed by the average of 123 in August, 1917—24 years, and 128 in July, 1928—35 years (eleven years afterward).

During the 55-year series under review, there were only eleven years throughout which sun-spots were not absent on observing days, while the least numbers of days when spots were not seen ranged between 2 and 14 in thirteen years. Of the total number of observing days in 55 years—16,679—there were 3,907, or 23.4%, when no spots were visible.

The scope of the *annual* totals of the Wolf relative numbers, as subjected to the coefficients mentioned in equalizing them to a standard of 1 for 3-inch aperture, is very wide, their rise and fall supposedly reflecting the spot areas involved. Thus, in the year 1892 the total computed was 24,831; in the year 1901, 543; and in the year 1913, 281—with little difference in the number of observing days, which varied between 333 and 344. In 1892 there were no days when spots were not in evidence, the number in 1901 being 288, and in 1913, 313, as above stated.

The *monthly* totals of the Wolf numbers ranged between an occasional zero at a spot minimum to 3,811 (August, 1917) at a maximum, their integrity depending on the adoption of appropriate coefficients as part of the formula.

Regarding the mutations of solar activity from day to day, it may be remarked that extremely short-lived spots are much less common than those whose existence covers several days, or often a complete rotation of the Sun. The peculiarities of the spot groups seem to affect their comparative permanency; those that increase in size and number of constituents having usually a longer duration than groups whose status is less subject to change. The variations, including those of shape and size, are so extensive that it is difficult to more than generalize, and many surprises await a consecutive observing program. Frequently, as the groups develop, numerous small evanescent spots make their appearance, and these I have often found to be at the verge of visibility with a four-inch object glass, comparable in magnitude to the faintest stars that can be seen with that aperture, but with the distinction that when the "seeing" is auspicious these dot-like spots bear increase of

magnification, as before noted.

Many of the reproductions of drawings do not correctly accentuate the marked contrast between umbra and penumbra—in this respect being inferior to photographs. However, the penumbrae vary somewhat in depth of tint, and the entirety of the penumbra bordering an immense spot group of irregular contour is frequently variable in hue to a slight extent, sometimes merging here and there almost imperceptibly into the photosphere. Another thing very often noticeable with the growth of a great group is the apparition of minor spots within the penumbra, and which evince changeable permanency as in the case of other spots composing a group, sometimes disappearing, so to speak, "over night."

It is well known that there is much difference in the length of time during which spot groups develop, some coming to maturity within a day or two, others growing more slowly, and their disappearance or absorption varies likewise. One gets accustomed to looking for "new" spots or groups at the eastern limb of the Sun, but these may originate anywhere within the spot zones, and many make a similar beginning on the unseen side of the disc, coming into view upon arrival at the eastern limb. Doubtless also "new" spots and groups run their full course out of sight, so that we can never know all that goes on within the zones. Yet with this taken into consideration, there seems to be sufficient stability in the life span of the more prominent groups to warrant believing that a carefully kept record reveals the greater part of the history of their development,—at times during successive rotations.

The areal extent of individual spot groups and surrounding faculae is occasionally enormous, now and then some billions of square miles, although at that but a small percentage of the area of the Sun's apparent disc, say 585 billions, really its hemispherical area of about 1,173 billion square miles.

The faculae also differ in size, form, and brilliancy, and are commonly associated with the spot groups as if belonging integrally thereto, yet often visible as a separate phenomenon. A great group of spots and faculae is one of the grandest sights imaginable, holding the observer's attention day by day in its seeming transit of the disc—constantly changing with complex cyclonic and magnetic activity—and from time to time reappearing more than once at the eastern limb, until the whole diminishes and is gradually engulfed within the hotter gases of the photosphere.

Something should be said concerning a sort of familiarity with the phenomena of the solar surface that attends long-continued observation. One thus becomes habituated to the principal visual characteristics of spots and faculae and to certain traits of similarity that must naturally appertain to their formation and development, even though neither follows exactness of pattern, whether of size, shape, or arrangement into groups. There is, too, an almost indefinable difference in the physical appearance of the Sun as between the maximum and the minimum of

a spot cycle, the consistence of the photosphere at the latter phase partaking more of a semblance of quietude as compared with the former—not unlike the opposites of calm and storm.

And it is hardly possible to devote a great deal of time to visual study of the Sun without wishing that unlimited telescopic power were attainable, such as could effect a reduction of equivalent distance to a few thousand miles, or, in other words, to bring the Sun as near as our telescopes do the Moon. One cannot but long for the clarity of lunar detail when applying high magnifiers to solar phenomena of vastly greater size but of microscopic dimensions as seen nearly four hundred times farther away, yet with a degree of compensation when some titanic outburst of latent forces offsets in a measure paucity of enlargement with lenses.

Still, on the other hand, we might realize that a view of the Sun with a power of 75 shows this, the nearest *star* in the sky, as a similar *sun* would appear in a telescope of unthinkably prodigious size if it were possible to employ a supposititious magnifying power proportionate to distance and absolute magnitude—probably, at the least, a million times greater. Thus entering the field of speculation, the question arises whether the stars also have spots and faculae, with distribution in cycles, and the mere statement of the case carries with it a conviction of the utter impossibility of ever being able to find a positive answer.

Whatever deductions are admissible from the 55-year record herewith, we may conclude that the observations necessary to establish laws of periodicity governing times either superior to or subordinate to the known cycle of eleven (±) years must cover a very much longer term, for, after all, any such is infinitely short when compared with the eons of infinitude of the Sun's existence.

OBSERVATIONS OF THE SUN

SUMMARY OF OBSERVING DAYS PER YEAR AND NUMBER OF DAYS WHEN NO SPOTS WERE SEEN

Year A.W.Q.	Number of Observing Days	Number of Days Spots not Seen	Year A.W.Q.	Number of Observing Days	Number of Days Spots not Seen
1889-7/1	159	87	1906	339	14
1890	324	197	1907	332	2
1891	328	19	1908	352	10
1892	333	0	1909	343	5
1893	330	0	1910	345	94
1894	329	0	1911	334	212
1895	322	0	1912	348	268
1896	322	6	1913	344	313
1897	333	32	1914	341	177
1898	326	56	1915	340	21
1899	336	136	1916	332	6
1900	341	178	1917	342	3
1901	335	288	1918	338	0
1902	334	252	1919	327	0
1903	330	74	1920	328	21
1904	331	5	1921	336	51
1905	348	5			

Year H.B.R.	Number of Observing Days	Number of Days Spots not Seen
1922	171	113
1923	218	145
1924	267	111
1925	238	47
1926	224	17
1927	216	5
1928	217	5
1929	245	2
1930	247	11
1931	243	58
1932	272	126
1933	312	231
1934	309	184
1935	277	36
1936	269	0
1937	250	0
1938	258	0
1939	255	0
1940	242	0
1941	315	32
1942	293	46
1943	314	91
1944-6/30	145	115

OBSERVATIONS OF THE SUN

Summary of Observing Day Averages, Yearly, of Wolf Relative Sun-Spot Numbers

Year A.W.Q.	Observing Days	Total Wolf Nos.	Average
1889-7/1	159	1,790	11
1890	324	4,032	12
1891	328	14,877	45
1892	333	24,831	75
1893	330	24,824	75
1894	329	24,362	74
1895	322	17,621	55
1896	322	11,127	35
1897	333	8,404	25
1898	326	6,596	20
1899	336	2,764	8
1900	341	2,757	8
1901	335	543	2
1902	334	1,226	4
1903	330	5,978	18
1904	331	11,016	33
1905	348	15,691	45
1906	339	11,144	33
1907	332	13,020	39
1908	352	9,927	28
1909	343	9,215	27
1910	345	3,919	11
1911	334	1,303	4
1912	348	774	2
1913	344	281	1
1914	341	2,234	7
1915	340	10,160	30
1916	332	11,855	36
1917	342	22,660	66
1918	338	16,375	48
1919	327	13,988	43
1920	328	8,344	25
1921	336	6,012	18
Total	10,882		

Year H.B.R.	Observing Days	Total Wolf Nos.	Average
1922	171	1,227	7
1923	218	1,556	7
1924	267	4,725	18
1925	238	8,813	37
1926	224	12,347	55
1927	216	13,951	65
1928	217	20,164	93
1929	245	19,588	80
1930	247	10,654	43
1931	243	6,005	25
1932	272	3,895	14
1933	312	1,812	6
1934	309	2,405	8
1935	277	8,071	29
1936	269	14,950	56
1937	250	21,382	86
1938	258	19,872	77
1939	255	18,621	73
1940	242	11,280	47
1941	315	12,188	39
1942	293	6,880	23
1943	314	3,908	12
1944-6/30	145	310	2
Total	5,797		

Observations by A.W.Q.	10,882
Observations by H.B.R.	5,797
Total observations	16,679

OBSERVATIONS OF THE SUN

SUMMARY OF MONTHLY AVERAGES OF WOLF RELATIVE SUN-SPOT NUMBERS
BASED ON OBSERVING DAYS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1889	..	..	..	..	..	..	15	24	10	5	0	8
1890	4	0	8	2	8	3	20	20	33	19	18	14
1891	29	35	11	43	60	76	57	28	71	49	39	35
1892	60	86	57	75	81	77	94	92	71	75	51	69
1893	62	65	59	70	83	79	79	114	70	62	79	73
1894	71	78	47	87	95	97	94	65	60	73	50	67
1895	58	52	50	58	46	61	39	86	44	65	39	53
1896	25	40	37	31	22	42	39	27	59	25	31	36
1897	45	28	26	32	21	12	22	31	38	15	8	28
1898	23	26	33	9	19	13	7	25	28	26	27	8
1899	12	7	13	11	4	14	11	1	4	8	5	10
1900	9	8	5	15	18	11	6	4	6	12	4	0
1901	0	1	3	0	7	3	0	0	0	2	3	0
1902	4	0	9	0	2	1	0	1	5	14	8	1
1903	6	13	10	18	9	9	23	22	9	30	36	32
1904	19	18	27	35	31	35	52	45	23	45	28	35
1905	39	57	51	29	33	34	62	44	43	54	66	32
1906	28	20	34	28	36	44	66	30	35	5	27	35
1907	48	65	37	29	25	35	38	38	55	43	35	27
1908	22	19	20	40	28	35	27	58	53	16	28	24
1909	34	27	37	20	23	16	23	15	22	39	37	31
1910	17	20	14	5	15	6	9	8	16	21	4	4
1911	3	6	5	12	8	1	1	3	3	2	3	2
1912	0	0	3	3	2	4	2	0	6	3	1	5
1913	1	2	0	1	0	0	1	0	1	1	0	2
1914	1	1	1	12	3	9	4	7	10	5	13	15
1915	16	31	24	26	22	40	46	55	28	28	20	20
1916	26	32	35	38	43	46	37	24	32	34	44	36
1917	38	42	55	47	74	76	77	123	90	46	52	69
1918	47	38	37	52	50	40	74	62	46	74	46	37
1919	32	47	47	39	56	70	45	53	37	35	28	22
1920	37	36	39	9	23	25	24	16	22	36	21	20
1921	22	16	17	23	15	22	27	21	12	13	12	15
1922	1	16	0	21	11	1	7	3	6	2	10	20
1923	0	0	5	8	1	9	1	0	17	15	18	1
1924	0	3	2	11	15	19	26	28	24	31	24	23
1925	3	20	11	26	38	37	35	25	59	65	55	92
1926	58	71	65	38	58	68	31	46	39	68	63	66
1927	72	75	76	105	76	63	43	38	66	61	57	51
1928	76	84	90	87	100	115	128	102	118	79	48	53
1929	76	79	78	70	84	96	86	91	37	63	91	107
1930	60	65	48	51	48	33	25	33	42	42	61	37
1931	16	55	43	49	28	14	19	17	21	10	18	19
1932	17	13	13	18	29	34	14	10	0	8	8	9
1933	14	23	14	3	2	7	0	0	5	3	0	0
1934	3	6	1	9	20	7	11	5	1	5	6	16
1935	17	12	16	6	20	36	34	28	35	48	50	46
1936	49	52	55	47	34	49	43	73	57	69	75	70
1937	93	104	61	119	93	92	104	90	79	79	45	51
1938	65	76	47	66	90	63	120	80	72	79	87	73
1939	66	72	52	93	96	79	73	75	89	71	61	39
1940	42	50	56	40	38	55	49	74	35	38	33	35
1941	44	31	42	24	24	47	59	45	44	46	34	28
1942	36	37	35	51	18	9	15	18	12	14	18	17
1943	7	18	22	24	13	5	10	16	9	5	8	12
1944	3	0	5	0	1	4	..	..	..	..	..	..

NOTE.—Observations during the period September 1—December 31, 1940, were made mostly by Dr. E. N. Fought, Philadelphia, with 4-inch Clark refractor.

The Work of William Gaertner

By LYMAN W. HIGGINS

Mr. William Gaertner celebrated his eightieth birthday on October 24 of this year. The entire organization participated in a fitting observance of the occasion which included formal presentation of a portrait, in oil, of himself.

Mr. Gaertner was born in Meresburg, Germany, in the year 1864, was educated and trained in the technical schools and scientific instrument industry of Europe and England. He founded his present business in 1896, seven years after coming to the United States.

In a long career of arduous endeavor he has made a distinct and lasting contribution to the field of modern science in the design and construction of high-grade precision instruments. Endowed with inventive genius and those qualities of close and patient application so necessary to the scientist and inspired by both an ardent love of his work and an ambition to excel in his chosen field, he has today a vast number of highly developed scientific instruments in general use throughout the world which stand as a monument to his professional knowledge and unusual creative ability.

His efforts and accomplishments have been a determining influence and an invaluable contribution to the establishment in this country of a precision scientific instrument industry that is unsurpassed throughout the world.

Part of Mr. Gaertner's early training was at the F. W. Breithaupt & Sohn firm of Cassel who were widely known makers of geodetic and astronomical instruments and also at A. Repsold & Sohn of Hamburg, makers of the highest type of astronomical and astrophysical equipment. In this country he was employed as an instrument maker in the United States Coast and Geodetic Survey and later with the Smithsonian Institution under Professor S. P. Langley and Doctor F. L. O. Wadsworth in the Astrophysical Observatory. During his stay there he came in contact with many important men of science among whom were Alexander Graham Bell, Hiram Maxim, Chanute, Rowland, and others. In the winter of 1895 he left Washington for Chicago where he became associated with the Kenwood Observatory.

In 1896 he established his own company and a short time later received an order from the University of Wisconsin for an Astro-Photometer. His success in the designing and construction of this highly specialized apparatus attracted the attention of Professors Michelson, Stratton, and Loeb of the University of Chicago, and they gave Mr. Gaertner abundant work for their departments. As far as is known, Mr. Gaertner was the first manufacturer for sale of the Michelson interferometer, and it is still one of the important items being offered in a long list of optical instruments. Another big customer of

that period was the Yerkes Observatory, which was dedicated in 1897. In 1896 Mr. Gaertner received his final papers of citizenship, and the decree was signed by his old friend, Professor S. W. Burnham, of the Yerkes Observatory, and at that time clerk of the Federal District Court of Illinois.

In 1910, an order was given Mr. Gaertner for the construction of a Photographic Zenith Telescope for the International Geodetic Association in accordance with the plans of Dr. Frank E. Ross. European astronomers of that period were skeptical as to its feasibility and success, but Mr. Gaertner undertook the design and construction of this delicate piece of work and it proved entirely satisfactory. It is now at the U. S. Naval Observatory. His success in making this instrument as well as the Astro-Photometer encouraged him to continue in this line and resulted in requests from all over the world for astronomical equipment. Many of these were accepted and fulfilled through the diligent efforts of himself and a small group of craftsmen working under him. Among the many instruments manufactured were coelostats, heliostats, spectroheliocopes, heliometers, prism transits, zenith transits, and many others.

The demand for astronomical equipment naturally included requests for an accurate comparator which involved the production of extremely accurate lead screws. This presented Mr. Gaertner with the opportunity to fulfill an ambition that had always been of special interest, namely to produce lead screws unequaled in accuracy. This ambition has been realized. Among the most accurate comparators in existence today are those designed and built by Mr. Gaertner. Precision lead screws have been and are being made for a great many applications from the small filar micrometer eyepiece, through linear and coördinate comparators of various ranges to the large lead screws incorporated in linear dividing machines. His interest in accurate screws was evidenced as far back as the early years in Vienna where he developed a ruling machine; in London, at the firm of Hilger where he designed a comparator; again while he was in Washington, D. C., where he came into contact with Professor Rowland at Johns Hopkins University, widely known for his success in producing accurate gratings; and yet again immediately after going into business for himself when he designed and constructed a machine for ruling special plates required by a Chicago firm in early work on the McDonough process of color photography.

He developed and perfected a method of correcting lead screws reducing the errors to a minimum previously unattainable. There are screws in use today that were made over 25 years ago, have been in constant use, and do not exhibit errors large enough to be distinguished from observational errors. However, Mr. Gaertner was not content to rest on his laurels. He constantly strove to improve and refine and today the ability of his company to produce screws of highest accuracy is still unsurpassed. This desire not to be satisfied that a product is

"good enough," but to make it the best that is humanly possible, to fulfill the requirements for which it is designed, is reflected in each of the wide variety of instruments now produced. This is evidenced by the fact that so many who require an instrument better than standard commercial equipment available come to him for assistance.

Because of the increasing demand for precision measuring equipment this field gradually became one of his major lines of interest and led to the development and perfecting of such instruments as the Micrometer Slide, Toolmaker Microscope, Filar Micrometer, Spherometer, and Cathetometer, as well as the linear and circular Dividing Machine and a large variety of related equipment.

Another line of optical instruments which were among the first produced in his small shop and later expanded to likewise satisfy demands for instruments of high quality were those classed as spectroscopic. They included spectroscopes, spectrometers from simple student types to large precision instruments for use where the highest accuracy is required; spectrographs both small and large, for work in the ultra-violet and infra-red. Mr. Gaertner manufactured the first Quartz Littrow Spectrograph produced in this country. Many innovations and improvements in design of instruments in this field were introduced such as the patened spiral dial for wave-length spectrometers and monochromators; the new two-lens quartz spectrograph and a large Infra-red Spectrograph incorporating many advanced features of design. Developments as yet unrevealed in infra-red spectrographic equipment are even now in progress.

Mr. Gaertner continues to be alert to the changing demands of science and industry and maintains close contact with the important university and industrial research laboratories of the country. Consequently many opportunities arise to satisfy his interest and desire to develop new and special instruments that require unusually high precision and quality.

A user who referred to one of these instruments as "the finest instrument of its kind available" states in a simple phrase the motivating purpose and desire behind every project Mr. Gaertner undertakes. Since many Gaertner instruments required the use of optical parts, microscopes and telescopes, he became interested in this field of endeavor and in 1916 acquired the optical shop of the famed optician Petitdidier. This shop is now located in the present building and here also stress is laid on the production of precision optical parts such as echelons, Lummer Gehrke plates, roof prisms, and optical flats, to namely only a few.

Mr. Gaertner was probably the first in the United States to establish an export business in scientific instruments and has constantly striven to promote the establishment in this country of a diversified precision instrument industry able to compete successfully with the best European products.

Following the first World War Mr. Gaertner moved into larger quar-

ters at the present location, 1201 West Wrightwood Avenue, Chicago, far removed from the street car, elevated, subway, and railroad whose vibrations are so detrimental to the manufacture and testing of delicate scientific instruments. Early this year a modern second-story addition was made to this plant.

Mr. Gaertner has collected about him a group of skilled and efficient experts chosen for their special training and ability in their particular fields to supervise the nearly three hundred workers now comprising the organization. He not only sees to it that the factory is provided with the latest machinery and equipment but also that his employes are afforded the opportunities and benefits that insure happy and congenial working conditions.

A complete list of the instruments manufactured by his company would indicate probably the largest variety of precision scientific optical and measuring instruments produced by any one concern.

The contribution Mr. Gaertner has made to the superlative efforts of our country in this present crisis is incalculable. His instruments are being used by all the armed services, research laboratories and industry.

In all the 80 years of his life the fruits of Mr. Gaertner's efforts have never been more needed or more appreciated than they are today. Nevertheless he does not consider his present achievements as the ultimate for which he has devoted his time and effort but together with the firm which he heads expects to make even greater contributions in the years of peace that will follow.

As a tribute to his notable achievemnts and as a recognition of his leadership in his field, Mr. Gaertner was awarded in October, 1924, the Howard N. Potts Gold Medal of the Franklin Institute of Philadelphia, "For distinguished work in science and arts." The medal was accompanied by a diploma of award from the Institute, which now adorns Mr. Gaertner's office. Throughout the years Mr. Gaertner has continued to serve as president, treasurer, and general manager of the Gaertner Scientific Corporation. He is a member of the American Astronomical Society, the Army Ordnance Association, the Chicago Association of Commerce, and the Press Club of Chicago.

Despite his long years of service and the arduous nature of his work, Mr. Gaertner still retains his youthful enthusiasm and buoyant spirit in his enterprise. He is a quiet, retiring man, but possesses an engaging personality which immediately inspires confidence and respect. Gifted with an usually analytical mind so well suited to his calling, he has kept alert to all impressions of progress and advancement, at the same time keeping closely in touch with his fellow man.

William Gaertner has built up an enterprise which stands as a monument to his name, and has made contributions to the advancement of science which have earned for him a well-deserved niche in the hall of fame.

The Planets in December, 1944

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern War Time subtract 4 hours, Central War Time, 5 hours, etc. The phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. During this month the sun will reach its farthest position south and will be well started northward by the end of the month. Its farthest position south defines the times of the winter solstice, the time of the shortest interval between sunrise and sunset in the northern hemisphere. The sun will move from Ophiuchus into Sagittarius.

Moon. The phases of the moon will occur as follows:

	d	h
Last Quarter	Dec. 7	15
New Moon	15	15
First Quarter	22	16
Full Moon	29	15

It will be farthest from the earth on December 8 and nearest the earth on December 23.

Mercury. On December 5, Mercury will be at greatest eastern elongation. On and near this date it will be nearly an hour and a half east of the sun and will, therefore, be above the horizon and, if conditions are favorable, be visible after sunset. Mercury will be a few degrees south of the sun which is an unfavorable circumstance for northern observers. It will be in a region in which there are no bright stars, and hence it will be recognized the more easily. However, it will move toward the sun very soon and on December 23 it will come to inferior conjunction, which means that it will set at practically the same time as the sun and hence be invisible.

Venus. Venus will be the brilliant evening star throughout the month. It will be high in the western sky at sunset and will attain its greatest brightness about Christmas time. This circumstance will doubtless give rise to comment and conjecture involving the part plays in the Christmas story.

Mars. Mars, having been passed by the sun about the middle of November, and moving eastward more slowly than the sun during this month, will rise earlier in the morning from day to day. At the beginning of the month it will be just above the horizon at sunrise, and at the end it will rise about an hour before the sun.

Jupiter. On December 18, Jupiter will be in quadrature, 90° west of the sun. This means that the planet will be near the meridian at sunrise. It will be approximately midway between the bright stars Regulus and Spica, and considerably brighter than either of them.

Saturn. On December 29, Saturn will be in opposition with the sun. It will, therefore, rise at sunset and be visible throughout the night. Because of the opposition it will have a slight apparent retrograde motion during this period. It will be quite far north of the equator and will afford a fine object for study and for entertainment for those equipped with even moderate telescopes.

Uranus. Uranus will be almost exactly two hours west of Saturn and in nearly the same declination. This statement applies during this month as it did

during November. (In the October issue the statement "west of the sun" should have been "west of Saturn.") Uranus, consequently, will also be observable throughout the night during the month.

Neptune. Neptune will be coming into more favorable position as the month advances. At the close of the month, it will rise a little before midnight, having been at quadrature with the sun on December 28. It will be in Virgo, northwest of Spica.

Asteroid Notes

By HUGH S. RICE

We are beginning to have a "run" on the minor planets again, for after the lapse of a few months several are coming into position for observation with small telescopes. Besides the three whose places are given in the subjoined ephemerides, we shall have, later, Vesta and Ceres, which "begin" in December, and still others following Ceres.

JUNO. We have this planet under almost nightly observation with Zeiss 50 mm. Juno was discovered by Harding on September 1, 1804, at Lilienthal, near Bremen, Germany. It was then at magnitude 7.5. Gauss, considered by Bell likely the world's greatest mathematical genius, was seemingly the first to compute its orbit. This was done by means of positions obtained by Bessel. Wachter and Möbius, two of Gauss' students, also worked on the orbit; and likewise Hind, Downing, Hase, and Merton, in later years. Thus several distinguished names appear in connection with this asteroid.

Juno's mean magnitude at opposition is given as 8.7 by the asteroid headquarters. The planet appears to be running brighter than this at the present apparition, for just now it is about 8 ± 0^m2, and becoming brighter. It is following the prescribed path as given in the computed ephemeris. It is passing by the star Epsilon Monocerotis at a distance of ¼°. We predict a visual magnitude of about 7.3 for the first of December. Opposition will occur on December 24.

The following positions are given to us by the courtesy of Dr. Dirk Brouwer of the Yale University Observatory. For Iris we predict magnitude about 10.3; and for Pallas about 8.0 for the middle of the period given.

EPHEMERIDES OF ASTEROIDS. FOR 0^h U.T.

3 JUNO (EQUINOX 1944.0)

1944	α h m	δ ° ′	1944	α h m	δ ° ′
Nov. 11	6 28.3	+ 2 4	Dec. 1	6 20.0	— 0 28
16	6 28.3	+ 1 24	6	6 20.0	— 0 28
21	6 27.4	+ 0 48	11	6 16.2	— 0 38
26	6 25.7	+ 0 16	16	6 12.1	— 0 41

7 IRIS (EQUINOX 1945.0)

1944	α h m	δ ° ′	1944	α h m	δ ° ′
Nov. 11	10 47.7	+ 2 59	Dec. 1	11 11.0	— 0 13
16	10 54.1	+ 2 9	6	11 15.8	— 0 57
21	11 0.1	+ 1 20	11	11 20.2	— 1 39
26	11 5.7	+ 0 33	16	11 24.2	— 2 18

2 PALLAS (EQUINOX 1945.0)

1944	α h m	δ ° ′	1944	α h m	δ ° ′
Nov. 21	11 6.2	−11 45	Dec. 11	11 35.8	−12 54
26	11 14.0	−12 7	16	11 42.5	−13 2
Dec. 1	11 21.6	−12 26	21	11 48.7	−13 5
6	11 28.9	−12 42			

Hayden Planetarium, American Museum of Natural History, New York, N. Y., October 23, 1944.

Occultation Predictions for December, 1944

(Taken from the *American Ephemeris*)

Date 1944	Star	Mag.	IMMERSION Greenwich C.T.	a	b	Angle E from N	EMERSION Greenwich C.T.	a	b	Angle E from N
			h m	m	m	°	h m	m	m	°
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
Dec. 1	372 B.Taur	6.1	1 37.6	−0.7	+1.5	82	2 43.8	−0.9	+1.7	246
1	BD+20°1105 *m*	5.9	9 52.4	−0.5	−2.2	122	10 46.7	−0.8	−0.3	238
2	BD+22°1416	6.3	5 12.6	−1.3	+3.4	37	6 7.3	−2.2	−2.2	312
2	*d* Gemi	5.2	11 55.3	−0.5	−0.8	74	12 49.0	+0.3	−1.9	300
3	149 B.Gemi	6.4	0 23.0	+0.7	+1.9	49	1 5.4	−0.2	+0.4	304
3	63 Gemi	5.3	0 38.4	+0.4	+1.5	74	1 32.0	−0.1	+1.0	279
4	102 B.Canc	6.5	10 18.1	−2.0	−0.1	73	11 22.2	−0.6	−2.9	324
4	ε Canc	6.3	10 20.2	−1.6	−1.1	100	11 36.9	−1.0	−2.0	296
8	γ Virg	4.2	5 7.3	+0.4	+3.7	50	5 38.6	−0.4	−2.2	348
27	δ Taur	3.9	7 49.6	−0.4	−1.1	84	8 48.0	−0.1	−1.0	260
27	64 Taur	4.8	8 23.4	0.0	−1.9	115	9 10.6	−0.2	−0.1	229
28	351 B.Taur	6.2	7 4.6	−1.0	−1.3	96	8 10.8	−0.7	−0.9	256
OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′										
Dec. 1	372 B.Taur	6.1	1 27.9	0.0	+1.7	67	2 26.4	−0.5	+1.3	262
1	BD+20°1105 *m*	5.9	9 49.9	..	..	155	10 19.2	..	..	201
2	BD+22°1416	6.3	4 50.4	0.0	+4.5	22	5 29.1	−2.4	−2.0	320
2	*d* Gemi	5.2	11 45.3	−0.8	−1.4	101	12 51.5	−0.5	−1.4	274
4	102 B.Canc	6.5	9 38.8	−2.1	−0.4	101	11 6.1	−1.8	−1.5	292
4	ε Canc	6.3	9 50.6	−1.8	−1.7	127	11 13.0	−2.2	−0.5	266
5	8 Leon	5.9	13 12.4	−0.9	−2.2	132	14 23.0	−1.0	−1.5	276
20	150 B.Capr	6.5	0 53.1	−0.8	−0.2	60	1 58.9	−0.6	−0.7	252
27	δ Taur	3.9	7 41.1	−0.9	−1.6	102	8 42.5	−0.8	−0.2	238
27	64 Taur	4.8	8 30.6	..	..	146	8 57.0	..	..	195
27	68 Taur	4.2	9 8.0	−0.8	+0.6	38	9 50.1	+0.3	−2.5	306
28	351 B.Taur	6.2	6 43.6	−1.6	−1.8	113	7 51.2	−1.6	+0.4	234
OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′										
Dec. 2	*d* Gemi	5.2	11 18.5	−1.6	−3.6	144	12 13.8	−2.5	+1.8	225
4	102 B.Canc	6.5	8 42.6	−1.7	−0.1	117	10 2.9	−2.0	+1.2	258
4	40 Canc	6.5	8 44.8	−1.1	+4.3	43	9 33.1	−2.1	−3.0	331
4	39 Canc	6.5	8 51.0	..	..	27	9 18.7	..	..	347
4	ε Canc	6.3	9 2.4	−2.0	−2.8	151	9 54.1	−1.9	+3.9	225
20	152 B.Capr	6.5	0 19.5	−1.1	+1.8	25	1 21.4	−2.6	−1.3	286
21	74 Aqar	5.9	5 11.4	+0.7	+3.3	0	5 38.2	−1.3	−4.0	307
27	δ Taur	3.9	7 0.6	−2.4	−2.0	116	8 1.8	−1.6	+2.2	211
27	68 Taur	4.2	8 34.3	−1.5	0.0	68	9 46.6	−1.1	−1.1	268
28	351 B.Taur	6.2	5 42.6	−2.5	−0.6	111	6 51.8	−1.7	−1.5	219
31	49 B.Canc	5.9	10 43.0	..	..	34	11 8.9	..	..	358

Date 1943	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
	OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′*									
Dec. 1	372 B.Taur	8.1	.. ...	..	..	...	2 10.1	—0.1	+1.5	247
2	BD+22°1416	6.3	4 18.2	—0.3	+2.2	51	5 21.1	—1.8	+0.2	288
2	Saturn	—0.1	7 10.6	—1.7	+3.6	37	8 9.6	—2.7	—2.8	314
2	*d* Gemi	5.2	12 1.7	—0.4	—3.2	143	12 51.7	—1.4	—0.5	234
4	39 Canc	6.5	9 10.7	—2.7	+1.9	67	10 26.2	—2.0	—3.0	322
4	40 Canc	6.5	9 12.1	—2.7	+1.3	75	10 34.9	—2.1	—2.5	315
4	102 B.Canc	6.5	9 37.1	—2.2	—2.8	142	10 54.5	—3.1	+1.0	250
5	8 Leon	5.9	13 42.8	+1.0	—5.7	181	14 16.4	—3.3	+1.7	231
19	Venus	—3.7	1 16.2	+0.7	+2.9	10	1 53.0	—1.9	—3.5	308
20	152 B.Capr	6.5	0 46.7	—1.6	—0.3	76	1 56.4	—0.6	+0.3	231
22	BD—8°6166	7.1	0 55.5	—3.3	—1.2	105	.. ...	..	..	...
22	BD—3°57	7.0	22 21.4	—0.2	+4.0	0	.. ...	..	..	...
24	BD+2°207	7.0	0 12.6	—0.7	+2.9	17	.. ...	..	..	...
25	382 B.Ceti	6.3	7 3.7	—0.8	+1.7	27	7 49.6	—0.3	—2.1	294
27	68 Taur	4.2	9 3.4	—0.8	—0.6	80	10 5.5	—0.2	—0.8	265

*Computation by Tecla Combariati and J. Lynn Smith, communicated by Captain J. F. Hellweg, Superintendent U.S. Naval Observatory.

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

It seems desirable, without waiting for reports which are over eight weeks late, to publish the data on meteors observed in the summer of 1944, most of them during the Perseid epoch. Results have been quite gratifying, and about 9100 will be found in the table. Besides these, there were many single meteors reported by others, or casuals by persons whose names appear in the table, which are not included. There are large areas of the country from which no report came, others furnished a few reports only, all from A.M.S. members. This seems to mean that the requests for observations, which was excellently handled by the press over about one-third of the country, was probably ignored by papers in the other two-thirds. Therefore numerous people, who would gladly have observed for a night or two, never realized the opportunity and our campaign suffered accordingly. Fortunately though, enough reports came in to give a good idea of the richness of the 1944 Perseid stream for several days on either side of the maximum date.

We are forever troubled by inability to get across to all our A.M.S. observers, to say nothing of our casual helpers, two important points. First, *our* unit is how many meteors one person sees per hour. Hence when a group count is sent in, unless proper precautions are taken, it is quite impossible to use the count statistically, combined with those made according to rule. Group counts are fine *if* each person counts every meteor he sees, no matter whether the same meteor is seen by every single member of the group. This direction seems so mysterious to many that another attempt will be made to explain it. People are under the erroneous impression that a small group can see all the meteors that are really visible at a given station. This opinion is utterly false. H. A. Newton, half a century ago, worked out that it would take about 30 people, assigned special areas of the sky, to record or rather count all the meteors visible from a given station. It is hence quite clear that a small group of people will not see all the meteors. Experience makes me believe that the best unit to use is the number one person sees per hour, in which opinion most meteor observers concur. This year some of our groups, for instance that at Joliet, Ill., were careful in this matter. Others, unfortunately, misunderstood or forgot instructions. I do not imply that the counts by these latter groups are not valuable, for they are. But I can only use them qualitatively in the following discussions, as their actual rates cannot be combined with the unit counts. The second important point is that some people (also including A.M.S. members) are careless about giving the exact hour and minute they begin and end their periods of observing, and information on which to base F, the visibility factor for the night. For instance, if it is very clear with no moonlight and one is far from artificial illumination, $F = 1.0$. This should mean 6 magn. stars are visible near zenith. For only 5 magn. stars to be visible there, $F = 0.7$; for 4 magn. stars, $F = 0.3$. These are rough values as much has to be left to the discretion of the observer when he reports the numerical value of F. Except for the maxima of the best showers, it is useless to observe in moonlight, at least unless the Moon is within 3 or 4 days of new.

Coming now to the reports, the Delta Aquarids had few observers so 1944 added little to our knowledge of them. For the Perseids, on August 11, the quarter Moon rose shortly after midnight. This meant that those hours when meteors are usually most numerous were interfered with by the Moon. When one remembers, therefore, that counts unimpeded by moonlight, perforce were made in the pre-midnight hours largely, the high rates recorded at many localities, by persons who counted only, indicate that the 1944 return was fully up to the average. Also the percentage of brilliant meteors and that of those leaving long-enduring trains were both good. The outstanding success was achieved by Lieut. R. J. Wood, U.S.N.R., who at Shawnee, Okla., organized groups of local children from 12 to 14 years old, and kept up their interest for four successive nights for very long observing periods up to 6 hours. This is unique in our annals. He himself plotted on all four nights, and the total for his group was 1255. This is a record which will not soon be rivaled. Two groups of high school pupils at Albertville, Ala., undertook counts on August 11, apparently without preliminary training or instructions from here. Our very active member, Frank Preucil at Joliet, Ill., sent in a splendid set of counts not only for himself, but on August 11 counts by a large group of the Joliet Astromical Society. The Junior Astronomy Club, attached to the Hayden Planetarium, in New York City, though they did not observe as a unit, sent in for July and

August the most extensive reports of any group, when we consider what a large per cent of the meteors were plotted. Mr. Webster Smith, president of the Interplanetary Communications Development Society of Bartlesville, Okla., also sent in an excellent group count for August 11. E. A. Halbach, our valued Wisconsin-North Illinois regional director, and a group from the Milwaukee Astronomical Society sent in good reports for August 11 and 12. Other reports seem to have been made by at most two people, the majority by one. However, the great interest in the extreme western states is due to the untiring activity of our regional director there, Prof. J. Hugh Pruett of the University of Oregon, who for years has done excellent work in meteoric astronomy.

The arrangement of the tables will be outlined, as our discussion will be based thereon. Column one, with station and observer, has been alphabetically arranged by states. When a group reported as such, one man's name is given to save space. The A.M.S. members have no special designation. The next column, headed D, gives the general direction the observer faced, when it is known; X implies that no special direction was chosen, or, for a group, that presumably all were. In the Time column, CW stands for Central War Time, etc. In the Rate column, no corrections are applied for F. This is left to any investigator who desires to use corrected rates. I have, however, given no uncorrected rates for $F < 0.6$, as corrections become too uncertain below that limit. It should be emphasized that the rates for plotters are smaller, all things being equal, by far than for counters. It is probable that most of our plotters, having had no great amount of experience, take from 1 to 3 minutes each to fully record a meteor. Strictly, therefore, the rates for plotters and counters are not really comparable. In the last column, c means that meteors were counted, p were plotted, d that each was quite fully described but not plotted.

With these points in mind it can be seen that for observers, well away from cities and who had clear skies on August 10, 11, 12, and 13, good rates were obtained. This is particularly true for those in the western states. The highest unit rate was 79 at Buhl, Idaho, on August 12, 15:25 to 16:25 M.W.T. With some moonlight present also! The highest group rate was 146 at Shawnee, Okla., on the same night from 13^h to 14^h C.S.T. As Miss Sandmeyer at Buhl and Wood's group at Shawnee both observed several consecutive nights, with a set program, their work seems to prove that August 12 not August 11 furnished the maximum despite 1944 being a leap-year. Her rates were 58 and 70, respectively; the group's 69+ and 98. Meteors were numerous on August 10 and even more so on August 13 and 14.

Near Philadelphia a number of excellent nights ended by August 11 being partly hazy, and August 12, when most local observers could work, being much worse. Duplicate observations made by various observers near here await reduction for heights, as do all the radiants which may be found on all maps. These should appear at a later date. The reports on long-enduring or drifting trains will be published elsewhere. Meantime we desire to thank everyone who aided in the summer observations and to express our sincere appreciation for their reports. We trust that, in years to come, all will put their experience to good use and undertake similar or more ambitious programs without waiting for annual reminders from us. In closing, attention should be called to the numerous men, in Army or Navy, who, despite their arduous duties, found time to devote to observing meteors and hence advancing science. While some are A.M.S. members, others are not. Special appreciation is due them all. A few

reports on work of previous years, which have just arrived, are added.

	D	Date m	d	Began	Ended	T	Min.	s →	F	Rate Unc.	Ob.	C
Alabama												
Albertville												
Rubey Taylor		8	11	12:00	12:30	CW	30	7	...	14	1	c
Horace McClain		8		12:00	12:30		30	3	...	6	1	c
Clarence Woodsham		8		12:00	13:00		60	35	...	35	1	c
Kyle Davis				12:30	13:00		30	44	...	(44)	2	c
Wayne Todd				12:30	13:00		30	29	...	58	1	c
Reported thru Dot George				11:00	13:30		150	15	...	6	1	c
				11:30	12:30		60	9	...	9	1	c
				11:30	13:30		120	29	...	14	1	c
				12:00	12:30		30	22	...	44	1	c
				12:30	13:30		60	15	...	15	1	c
				12:30	14:00		90	20	...	13	1	c
California												
Burlingame												
Miss M. Deane		9	11	11:30	12:30	PW	60	25	...	25	1	c
Davis												
Miss D. E. Beetle	X	8	11	9:50	10:50		60	50	...	..	6	c
" "	X		12	9:27	10:59		92	59	...	..	6	d
" "	X			14:11	15:16		65	55	...	..	6	d
Encino												
J. E. Atwood		8	11	11:52	13:52	PS	120	9	1.0	4	1	p
" "		8	20	13:06	15:06		120	13	1.0	6	1	p
" "			cas.					9	1.0	4	1	p
Fresno												
Dr. J. B. Bostick		8	7	15:18	15:48	PW	30	8	0.4	16	1	c
" "			8	12:30	13:00		30	3	...	6	1	c
" "			10	16:50	17:20		30	6	...	12	1	c
" "			11	11:37	12:07		30	11	...	22	1	c
Mrs. E. C. Churcher			11	11:20	11:45		25	6	...	14	1	c
Dr. J. B. Bostick			12	9:22	9:52		30	20	0.6	40	1	c
" "				11:45	12:15		30	25	0.6	50	1	c
" "			13	9:30	10:30		50	11	...	11	1	c
" "				17:00	17:20		20	6	0.5	..	1	c
" "			14	12:10	12:30		20	7	...	21	1	c
" "			16	16:37	17:07		30	7	...	14	1	c
" "			17	16:25	17:55		??	6	...		1	c
" "			cas.					7	...		1	c
J. Blaser		8	11	9:15	10:15		60	25	...	25	1	c
"		8	12	11:15	12:15		60	20	...	..	2	c
"		8	13	9:30	10:30		60	6	...	..	2	c
Mrs. J. Blaser		8	13	13:00	13:30		30	22	...	44	1	c
Glendale												
L. C. F. Johnson		8	11	14:10	15:00		110	20	0.5	..	.	c
" "		8	12	15:30	16:00		30	5	0.3	..	.	c
Palo Alto												
Dr. H. Power		8	11	11:10	11:40		30	11	...	22	.	c
Redwood City												
A. M. Culbertson		8	11	10:00	11:30		90	24	...	16	1	c
San Francisco												
Lieut. V. E. Senter,	USN	8	10	10:35	11:35		60	31	...	..	2	c
" "		8	11	10:30	11:30		60	56	...	..	2	c
Victorville												
Sgt. M. R. Bronson		8	11	10:20	10:40		20	37	1.0	(37)	3	c
Pfc. I. M. Grenfield		8		10:40	11:00		20	40	1.0	(40)	3	c
Pfc. . R. R. Brunner		8		11:00	11:20		20	33	1.0	(33)	3	c
Connecticut												
Hartford												
Mrs. G. Ehman		8	9	9:50	10:45	ES	55	7	1.0	8	1	c

	D	Date m	d	Began	Ended	T	Min.	s →	F	Rate	Unc.	Ob.	C
Mrs. G. Ehman		8	10	12:15	15:02		167	31	0.5	..		1	c
"		8	11	8:10	10:03		113	9	0.8	4		1	c
"		8		12:18	15:00		162	18	0.5	..		1	c
"		8	12	8:40	9:40		60	7	0.4	..		1	c
G. Ehman			10	12:15	15:02		167	19	0.5	..		1	p
"			11	12:18	15:00		162	13	0.5	..		1	p
Nangatuck													
J. J. Wriun		8	10	12:21	14:20	EW	119	22	0.7	..		2	d
"		8	11	12:04	13:43		99	19	0.5	..		2	d
"		8	12	11:15	13:00		105	8	0.8	..		2	d
Delaware													
Wilmington													
R. M. Hukill		8	11	12:45	13:55		65	48	...	44		1	c
D. C.													
Washington													
"		8		17:00	17:30		30	5	...	10		1	c
"		8	11	12:30	13:00		30	8	...	16		1	c
"		8		17:00	17:30		30	5	...	10		1	c
Florida													
Sarostota													
Miss J. Griffith		8	11	12:30	15:00		120	28	...	14		1	c
Idaho													
Buhl													
Miss E. Sandmeyer		7	24	10:30	11:30	MW	60	2	...	2		1	c
"		7	27	15:45	16:45		60	7	...	7		1	c
"		8	6	10:30	11:30		60	4	...	4		1	c
"		8	7	10:30	11:30		60	11	...	11		1	c
"		8	9	11:00	12:00		60	21	...	21		1	c
"		8	10	11:15	12:15		60	36	1.0	36		1	c
"		8	11	11:00	12:00		60	43	1.0	43		1	c
"		8		12:00	13:30		90	74	1.0	50		1	c
"		8	12	15:25	16:25		60	79	0.6	79		1	c
"		8		16:30	17:30		60	61	0.6	61		1	c
"		8	14	11:15	12:15		60	36	1.0	36		1	c
Illinois													
Joliet													
F. Preucil		7	15	10:15	10:45	CW	30	6	1.0	12		1	c
"			18	9:00	10:00		60	2	0.8	2		1	c
Wm. Preucil			19	10:00	11:00		60	3	1.0	3		1	c
F. Preucil			21	10:15	11:15		60	10	1.0	10		1	c
"			24	10:40	11:40		60	12	1.0	12		1	c
"			27	9:30	9:45		15	2	0.6	..		1	c
"			28	15:50	16:35		45	9	1.0	12		1	c
"			29	11:00	12:00		60	6	0.5	..		1	c
"		8	8	11:10	11:40		30	2	1.0	4		1	c
"			9	10:00	10:30		30	2	1.0	4		1	c
"	E		10	11:00	12:00		60	19	1.0	19		1	c
Wm. Preucil	N			11:00	12:00		60	27	1.0	27		1	c
F. Preucil	E		11	9:00	10:00		60	26	1.0	26		1	c
Wm. Preucil	N			9:00	10:00		60	30	1.0	30		1	c
R. Price	Z			10:05	11:05		60	33	1.0	33		1	c
R. Mulik	E			10:05	11:05		60	22	1.0	22		1	c
J. Brodeske	SE			10:05	11:05		60	8	1.0	8		1	c
F. Fleever	S			10:05	11:05		60	21	1.0	21		1	c
B. H. Wilson	SW			10:05	11:05		60	23	1.0	23		1	c
E. Noll	W			10:05	11:05		60	18	1.0	18		1	c
W. Feible	NW			10:05	11:05		60	19	1.0	19		1	c
M. Jordan	N			10:05	11:05		60	26	1.0	26		1	c
R. Cooke	NE			10:05	11:05		60	18	1.0	18		1	c
F. Preucil	NE			10:45	12:45		60	36	1.0	36		1	c

	D	Date m	d	Began	Ended	T	Min.	s →	F	Rate Unc.	Ob.	C
R. Price	WZ			11:45	12:45		60	40	1.0	40	1	c
R. Cooke	SE			11:45	12:45		60	24	1.0	24	1	c
J. Brodeske	S			11:45	12:45		60	22	1.0	22	1	c
F. Preucil	NE		12	9:15	10:15		60	23	1.0	23	1	c
Wm. Preucil	N			9:15	10:15		60	21	1.0	21	1	c
F. Preucil	NE			11:45	12:45		60	33	1.0	33	1	c
F. Preucil	E		13	9:20	10:20		60	5	1.0	5	1	c
Wm. Preucil	N			9:20	10:20		60	9	1.0	9	1	c
F. Preucil			14	9:30	10:00		30	1	0.7	2	1	c
Wm. Preucil				9:30	10:00		30	0	0.7	0	1	c
Indiana												
Hope												
A. G. Krespach	X	8	11	12:30	13:00		30	80	0.9	(20)	6	c
Iowa												
Des Moines												
M. C. Johnson, Jr.	E	7	21	15:00	16:02		62	8	1.0	8	1	p
"	E		26	15:00	16:00		60	1	0.8	1	1	p
"	E		28	16:00	17:00		60	2	0.5	2	1	p
"	N	8	11	14:00	15:00		58	9	0.5	..	1	p
Dubuque												
T. B. Laughlin			11	10:45	11:45		60	43	0.8	43	1	c
N. P. Klass			11	10:45	11:45		60	17	0.8	17	1	p
"				11:45	12:45		60	31	0.8	31	1	p
Wm. Barragy	NE		12	11:45	14:45		180	56	0.7	19	1	c
J. E. Brown	SE			11:45	14:45		180	67	0.7	22	1	c
K. Klein	SW			11:45	14:45		180	81	0.8	27	1	c
J. Permantier	NW			11:45	14:45		180	89	1.0	30	1	c
Group average	X			10:45	11:45		60	84	...	(21)	4	c
N. P. Klass				10:45	14:45		240	74	0.8	18	1	p
Louisiana												
W. Monroe												
Lt. W. S. Houston	NE		11	10:00	11:00		60	7	0.9	7	1	p
Lt. F. Libby	SW			10:00	11:00		60	14	1.0	14	1	p
Capt. A. Phelps	S			10:00	11:00		60	6	1.0	6	1	p
Lt. A. L. Harris III	NE			10:00	11:00		60	7	0.9	7	1	p
Maine												
Cape Elizabeth												
R. M. Dole		8	9	8:30	9:30	EW	60	4	1.0	4	1	p
"			10	12:00	13:30		60	13	0.6	13	1	c
"			11	10:30	14:45		255	101	0.4	..	1	p
"			12				...	4	0.2	..	1	p
Maryland												
Catonsville												
Louise Merz		8	11	12:00	12:30		30	16	0.8	22	1	c
Baltimore												
L. H. Crone	NE						...	4	0.8	..	1	p
R. Hochschild			11	11:30	12:30		60	11	0.8	..	2	c
J. L. Leerman		8	13	15:55	17:25		90	13	...	9	1	c
"			14	12:15	13:30		75	7	...	6	1	c
"			15	14:55	15:55		60	5	...	5	1	c
Massachusetts												
Cambridge												
Wm. Liller		8	8	13:10	14:57	ES	107	26	0.8	14	1	p
"			9	12:52	14:25		93	17	0.7	11	1	p
"			10	13:06	15:06		120	30	0.8	15	1	p
"			11	13:00	15:05		120	28	0.5	14	1	p
S. Hadley												
Miss A. Farnsworth	NE	8	11	11:18	12:18	EW	60	26	...	26	1	c
Michigan												
Adrian												
Dr. H. K. Powell		8	11	10:40	13:50		70	11	...	..	1	c

	D	Date m	d	Began	Ended	T	Min.	s →	F	Rate Unc.	Ob.	C
Lansing												
B. Darling		8					...	116	...	..	1	p
Minnesota												
Brainerd												
K. Widing	NE	8	10	14:30	14:50	CW	20	9	...	..	1	c
"			11	15:55	16:05		10	8	...	..	1	
New Hampshire												
Kearsarge												
Dr. W. L. Holt			11	9:30	12:00		150	42	0.7	17	1	c
New Jersey												
Clifton												
Chas. Weidemann	W	8	11	9:00	10:00	EW	60	40	0.8	40	1	p
"	NW			10:00	11:00		60	30	0.8	30	1	p
"	N			11:00	12:00		60	20	0.8	20	1	p
"	N			12:00	13:00		60	12	0.5	..	1	p
"	N			13:00	14:00		60	5	0.4	..	1	p
Peterson												
R. Chlebrikow		8	10	11:50	15:00		190	21	0.3	..	1	p
"			11	10:00	16:00		360	53	0.3	..	1	p
"			12	10:35	16:35		360	36	0.3	..	1	p
Riverton												
R. D. Latch		8	9	16:50	17:20		30	3	0.3	..	1	c
"				10:45	11:45		60	22	1.0	22	1	c
Ventuor												
E. B. Rifkin		8	11	15:00	16:10		70	10	0.5	..	1	p
New York												
Utica												
War of. W. P. Horton	E	8	10	13:20	14:35	EW	75	12	0.5	..	1	p
N. Bronx												
Helen Staff		8	10	11:30	12:00		30	12	0.6	24	1	c
"			11	12:00	13:00		90	26	0.6	25	1	c
"			12	12:00	13:00		60	23	0.6	23	1	c
Bronx												
E. Epstein		8	11	8:55	11:03	ES	128	16	0.6	7	1	p
"			12	9:58	11:30		92	9	...	6	1	p
B. Stowe			17	9:15	10:30		75	9	1.0	7	1	p
"		7	22	9:15	14:45		330	30	1.0	6	1	p
"		8	11	8:45	15:35		410	90	0.6	13	1	p
"			12	9:00	13:00		240	27	0.7	7	1	p
"			19	10:00	14:30		240	32	1.0	8	1	p
"			26	11:00	13:15		135	14	1.0	6	1	p
A. Taleporos		7	30	10:00	15:20		320	71	0.9	13	1	d
"		8	6	9:40	15:30		350	102	1.0	18	1	d
Sullivan County												
A. Taleporos		8	9	9:59	11:45		106	25	0.9	4	1	d
"			11	9:50	12:30		160	57	0.7	24	1	d
Bronx												
K. Weitzenhoffer		6	30	14:10	15:00		50	3	0.7	4	1	d
"		7	17	14:00	15:00		60	3	0.8	3	1	d
"		7	21	9:30	10:00		30	3	1.0	6	1	d
"				14:00	15:00		60	3	1.0	3	1	d
"			22	12:45	14:45		120	13	1.0	6	1	d
"			25	14:00	15:15		75	6	0.8	5	1	d
"			28	12:00	12:30		30	5	0.6	10	1	d
"		8	10	9:15	11:15		120	15	0.8	8	1	d
"			12	9:00	11:30		150	12	0.3	..	1	d
"			18	13:30	14:10		40	4	1.0	6	1	d
"			19	11:15	12:45		90	14	1.0	9	1	d
"				13:30	14:15		45	9	1.0	12	1	d
"			26	11:30	12:45		75	9	1.0	7	1	d
"		9	16	9:30	10:45		75	5	0.7	4	1	d

	D	Date m	d	Began	Ended	T	Min.	s →	F	Rate Unc.	Ob.	C
K. Weitzenhoffer		8	10	13:35	15:45		130	14	0.5	..	1	p
"		8	11	8:45	15:45		400	71	0.6	10	1	p
North Dakota												
Bismarck												
B. Finney		8	11	10:55	13:05	MW	120	58	1.0	..	2	c
S. S. Hagen		8	11	9:30	10:30		60	40	1.0	40	1	c
Ohio												
Columbus												
M. Paliobagis		8	11	10:22	13:17	EW	175	30	1.0	..	1	d
Oklahoma												
Bartlesville												
W. Smith	X	8	11	9:30	10:30		60	15	0.3	..	g	c
"	X			10:30	11:30		60	59	1.0	..	g	c
"	X			11:30	12:00		30	33	0.5	..	g	c
"	X			12:00	13:00		60	73	1.0	..	g	c
"	X			13:00	13:30		30	44	0.9	..	g	c
Shawnee												
Lt. R. J. Wood, USNR	X	8	10	9:30	10:30	CS	60	61	1.0	..	g	c
"	X			10:30	11:30		60	52	1.0	..	g	c
"	X			11:30	12:30		60	67	1.0	..	g	c
"	X			12:30	13:30		60	57	1.0	..	g	c
"	X	8	11	9:00			60	36	0.8	..	g	c
"	X			10:00			60	56	0.8	..	g	c
"	X			11:00			60	88	1.0	..	g	c
"	X			12:00			60	94	1.0	..	g	c
"	X			13:00	13:45		45	71	1.0	..	g	c
"	X	8	12	9:00	10:00		60	75	1.0	..	g	c
"	X			10:00	11:00		60	112	1.0	..	g	c
"	X			11:00	12:00		60	90	1.0	..	g	c
"	X			12:00	13:00		60	66	1.0	..	g	c
"	X			13:00	14:00		60	146	1.0	..	g	c
"	X			14:00	14:30		30	13	0.4	..	g	c
"	X	8	13	9:00	10:00		60	70	1.0	..	g	c
"	X			10:00	11:00		60	67	1.0	..	g	c
"	X			11:00	12:00		60	61	1.0	..	g	c
"		8	10	9:30	13:10		220	79	1.0	22	1	p
"			11	9:00	13:46		286	80	0.9	19	1	p
"			12	8:30	14:15		345	79	1.0	14	1	p
"			13	9:00	12:00		180	15	1.0	5	1	p
Oregon												
Bend												
Mrs. W. Horsell		8		.....	.....		..	14	...	..	.	
Echo												
Mrs. G. H. Frederick		8	10	9:40	10:45	PW	60	13	...	13	1	c
"		8	11	9:30	10:30		60	36	...	36	1	c
Eugene												
Jack Mervyn		8	8	11:00	11:45		45	18	...	24	1	c
"			9	9:45	10:30		45	18	...	24	1	c
"			10	9:45	10:30		45	31	0.9	41	1	c
"			11	9:45	10:30		45	36	0.9	48	1	c
"			12	9:45	10:30		45	17	0.9	23	1	c
Mrs. J. H. Pruett		8	11	10:00	11:00		60	35	0.9	35	1	c
"			12	10:00	11:00		60	15	0.9	15	1	c
Mrs. J. H. Pruett		8	11	10:00	10:00		60	35	0.9	35	1	c
"			12	10:00	11:00		60	15	0.9	15	1	c
Miss H. Thompson		8	11	10:00	12:00	PS	60	44	0.9	44	1	c
Mrs. H. T. Thompson		8	10	9:55	11:10	PW	15	22	0.9	17	1	c
"			11	10:30	11:30		60	43	0.9	43	1	c
"			12	10:45	11:45		60	16	0.9	16	1	c
Grants Pass												
B. R. Bones		8	11	11:15	12:15		60	43	1.0	43	1	c

	D	Date m	d	Began	Ended	T	Min.	s →	F	Rate	Ob.	C
Pendleton										Unc.		
Mrs. F. M. Whetsel	X	8	10	9:30	10:30		60	34	...	..	4	c
"	X	8	11	9:30	10:30		60	74	...	..	4	c
"	X			10:30	11:00		30	63	...	..	4	c
Scio												
C. N. Young		8	11	10:15	11:00		45	44	...	59	1	c
Silverton												
Alice K. Jensen		8	12	12:40	13:50		70	55	...	47	1	c
"			13	13:05	14:00		55	35	...	38	1	c
Warm Springs												
T. Courtney			11	11:10	12:10		60	33	...	33	1	c
"			12	10:30	11:00		30	8	...	16	1	c
Pennsylvania												
Bryn Athyn												
Mrs. R. M. Cole		8	11	11:25	12:42	EW	62	17	0.7	17	1	d
Cook Observatory												
R. K. Marshall	NE	8	8	9:15	14:00		..	15	0.7	..	1	
"		8	9	9:00	13:00		..	12	...	..	1	
"			10	9:00	13:45		..	48	...	..	1	
"		8	11	9:00	15:15		315	54	0.4	..	1	
Flower Observatory												
C. P. Olivier	NE	8	10	10:15	12:00	ES	105	24	0.7	14	1	p
A. McElroy		8	11	8:05	10:15		130	11	0.4	..	1	p
Fort Washington												
R. Price	N	8	11	11:00	12:30	EW	90	17	0.5	..	1	d
Highland Park												
J. O. Rule			8	11:15	12:30		75	9	0.7	7	1	c
"			10	9:25	11:00		95	10	0.7	6	1	c
"				11:00	12:00		60	11	0.7	11	1	c
Huntingdon												
D. Fisher, Jr.		6	12	10:05	11:25		80	4	0.7	3	2	c
"			17	10:30	12:00		90	4	0.7	3	2	c
"			21	11:30	12:15		45	3	0.7	4	2	c
"			26	11:15	11:45		30	1	0.7	2	2	c
"		7	16	10:00	12:00		120	5	0.7	2	2	c
"		8	10	12:04	13:04		60	22	0.5	..	2	c
"			11	10:00	11:00		60	24	0.4	..	6	c
"			12	11:00	11:20		20	4	0.4	..	4	c
"				13:11	13:51		40	6	0.4	..	2	c
North Hills												
Miss E. F. Reilly		8	12	10:30	14:00		210	22	0.4	..	1	p
W. W. Haas				10:24	14:03		219	19	0.4	..	1	p
Klein				10:45	13:52		127	13	0.4	..	1	p
Smith				11:00	13:00		120	16	0.4	..	1	p
R. V. Shutts				10:30	14:00		150	13	0.4	..	1	p
Wm. Schmitt				10:26	14:06		220	22	0.4	..	1	p
Olney												
E. E. Gehret		8	10	11:00	13:00		120	34	0.7	17	1	c
"			11	11:00	14:00		180	62	0.6	21	1	c
"			12	11:30	13:00		90	16	0.5	..	1	c
Philadelphia												
Aaron Liss		8	10	8:32	12:43		251	47	0.8	..	1	d
"		8		.....	.....		..	6	...	..	1	d
Miss E. F. Reilly		8	10	11:10	12:15		65	8	0.7	7	1	c
Mrs. D. W. Scheer	N	8	11	9:30	13:05		215	34	0.5	..	1	c
Phoenixville												
C. P. Olivier	N	9	11	9:39	12:39	ES	180	41	0.6	14	1	p
W. L. Olivier		8	11	11:09	11:39		30	11	0.6	22	1	c
Ted Rhoad	NE	8	11	9:39	10:39		60	30	0.6	30	1	c
"	NE			10:39	11:39		60	30	0.6	30	1	c
"	NE			11:39	12:39		60	21	0.6	21	1	c

	D	Date m	d	Began	Ended	T	Min.	s →	F	Rate	Unc.	Ob.	C
C. P. Olivier	Z	8	12	9:40	13:00		200	25	0.4	..		1	p
State College													
J. H. Schilling		8		9:00	11:15		135	6	0.8	3		1	p
"			9	10:00	11:30		90	6	1.0	4		1	p
"			10	9:30	12:00		150	16	1.0	6		1	p
"			11	11:30	13:30		120	14	0.6	7		1	p
"			12	10:00	14:00		240	30	0.7	8		1	p
Washington Crossing													
H. L. Herbert			10	.....	.....		90	21	0.9	..		1	c
"	N	8	11	9:00	10:00		60	18	0.8	18		1	c
"	N			10:00	11:00		60	21	0.8	21		1	c
"	N			11:00	12:00		60	18	0.8	18		1	c
South Dakota													
Dell Rapids													
Betty Long		8	9	11:00	12:15	MW	75	10	...	8		1	c
"			10	10:00	13:00		180	47	1.0	16		1	c
"			11	10:50	14:20		210	109	1.0	31		1	c
"			12	11:35	12:15		40	6	1.0	9		1	c
Sioux Falls													
W. J. Duhon			11	12:00	15:00		180	71	..	24		1	c
Tennessee													
Nashville													
Betty Jane		8	11	12:15	13:15	CW	60	32	...	32		1	c
Texas													
Corpus Christi													
R. O. Gorson, U.S.A.		8	12	10:45	12:00		75	28	0.9	22		1	d
"				14:00	15:00		60	36	...	36		1	d
"				15:00	16:00		60	33	...	33		1	d
"				16:00	17:00		60	36	...	36		1	d
"				17:00	18:00		60	37	...	37		1	d
Kerrsville													
Father Kemper		8	11	11:00	13:00		120	7	...	..		1	d
"			12	11:00	12:30		90	10	...	..		1	d
R. J. Costella			11	10:00	11:00		60	3	...	..		1	d
Charlene Johnson			12	13:00	13:30		30	7	...	..		1	d
Virginia													
Colonial Beach													
Donald Fox		8	11	12:00	12:30	EW	30	13	...	26		1	c
Vermont													
Bethel													
W. W. Parker		8	7	11:00	12:00		..	4	...	..		1	c
"	Z		8	9:20	11:20		120	13	1.0	7		1	d
"			9	9:15	10:00		45	10	1.0	13		1	d
"			10	9:30	11:00		90	23	0.6	16		1	d
"			11	8:20	10:08		48	23	0.7	28		1	d
"				10:38	12:00		82	54	0.7	22		1	d
"			12	9:30	9:45		15	8	0.7	..		1	c
Washington													
Longview													
Margy Bidlake		8	9	11:00	12:00	PW	60	27	0.5	27		1	c
"			10	11:30	12:30		60	32	1.0	32		1	c
"				12:30	13:30		60	46	1.0	46		1	c
"			11	12:00	13:00		60	29	0.7	29		1	c
"			12	12:00	13:00		60	34	0.7	34		1	c
"				13:00	14:00		60	41	0.7	41		1	c
Wisconsin													
Polonia													
L. J. Cieminski		8	11	10:00	10:30	CW	30	33	0.5	..		4	c
Milwaukee Astronomical Society Observatory													
Group		7	29	13:20	14:16		..	51	1.0	..		4	d
E. A. Halbach				.....	.....		..	24	1.0	..		1	p

	D	Date m d	Began	Ended	T	Min.	s →	F	Rate	Unc.	Ob.	C
Edwin Schoenke			.....	.....		..	14	1.0	..		1	p
Miss Marie Auton			.....	.....		..	9	1.0	..		1	p
A. R. Ball			.....	.....		..	9	1.0	..		1	p
E. A. Halbach		8 11	11:00	12:00		60	22	...	22		1	c
"			12:00	13:00		60	23	...	23		1	c
"			13:00	14:00		60	35	...	35		1	c
"		12	12:00	13:00		60	24	...	24		1	c
"			13:00	14:00		60	28	...	28		1	c
"			14:00	15:00		60	33	...	33		1	c
"			15:00	16:00		60	42	...	42		1	c
"		8 11	11:00	14:00		..	31	...	..		1	p
Mrs. E. A. Halbach			11:00	14:00		..	13	...	..		1	p
Miss Marie Auton			11:00	14:00		..	4	...	..		1	p
L. E. Peterson			11:00	14:00		..	8	...	..		1	p
Edwin Schoenke			11:00	14:00		..	8	...	..		1	p
E. A. Halbach		8 12	12:00	16:00		..	35	...	..		1	p
Mrs. E. A. Halbach			12:00	16:00		..	18	...	..		1	p
Miss Marie Auton			12:00	16:00		..	5	...	..		1	p
C. Griesbacher			12:00	16:00		..	11	...	..		1	p
			1942									
New Jersey												
Titusville												
Mrs. J. J. McKeon		8 11	9:30	13:00	EW	210	19	0.2	..		1	p
			1943									
"		6 5	11:45	15:45		240	14	1.0	4		1	p
"		8 5	10:00	12:00		120	19	1.0	10		1	d
"			15:08	16:10		62	16	1.0	16		1	d
"	NE	6	13:30	16:00		150	29	1.0	12		1	d
Mrs. J. Potter	NE		13:30	16:00		150	24	1.0	10		1	d
Rev. J. Potter	E		13:30	16:00		150	24	1.0	10		1	d
Mrs. J. J. McKeon		14	12:20	14:20		120	11	0.3	..		1	p
			1940									
Wisconsin												
(Near Dubuque, Iowa)												
P. N. Klass		7 23	8:45	9:45	CS	60	10	1.0	10		1	p
"		8 4	9:10	10:10		60	12	1.0	12		1	p
			1941									
"		8 13	9:00	10:41		101	25	0.9	30		1	p

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, October 10, 1944.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

A Photograph of a Meteor Trail Made with the Crossley Reflector

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ABSTRACT

A description is given of the trail of a bright meteor appearing on a recent Crossley Reflector plate, and an attempted method of detecting the effect of the angular diameter of the meteor is outlined. A photographic light curve of the meteor was obtained and is shown in an accompanying diagram (Figure 2).

On the evening of 1944 July 20, the trail of a bright meteor appeared on a plate exposed with the Crossley Reflector of the Lick Observatory (aperture 36½ inches, focal length 17½ feet) in search of a minor planet. In view of the small angular field of the Crossley Reflector (about 50′ × 60′, on a 3¼ × 4¼-inch plate), obtaining this photograph was a rather unusual event. The meteor was not observed visually; so we can set only the beginning and the end of the exposure as the time limits; the plate was exposed 15 minutes, from $21^h\,25^m\,44^s$ to $21^h\,40^m\,44^s$ P.S.T., on July 20. The trail is quite smooth and is unbroken by any irregularities, but there is a well-marked fading-off at one end. It is not possible, of course, to say in which direction along the trail the meteor moved, but a likely assumption is that its zenith-distance was increasing. In order to determine which end of the trail had the lesser zenith-distance, thus indicating the direction from which the meteor came, the points where the trail entered and left the plate were measured and reduced with the aid of stars 64237, 64585, and 64615 of the Hyderabad astrographic plate at $\alpha\ 18^h\,16^m$, $\delta - 22°$. The results were as follows, for the mean equinox of 1900.0:

Strong End of Trail

$\alpha = 18^h\,19^m\,52^s.4$, $\quad \delta = -21°\,50'\,53''$

Weak End of Trail

$\alpha = 18^h\,16^m\,15^s.1$, $\quad \delta = -22°\,14'\,11''$

From these coördinates it follows that the weak end of the trail, where it passes off the plate, had a zenith-distance about 11′ greater than the other end. Therefore, lacking better criteria, we shall assume that the meteor moved from east to west along the trail, so that the formation of the image of the weak end represents the later event.

The original purpose of this study was to take advantage of the high resolving power of the Crossley Reflector, to investigate the trail from the photometric standpoint, in order to determine whether the luminous portion of the meteor had an appreciable angular diameter or whether it behaved effectively like a point source of light. The method of approach was to be as follows: microphotometer tracings across the trail at frequent intervals would make it possible to obtain the relative intensities of light necessary to produce such a silver deposit. On the reasonable assumption that the growth of the image, due to turbidity at right angles to the trail, would be governed by the same law as that which controls the growth of star images,* the diameter of the trail at the points where relative intensities were measured could be compared with the diameters of stars of known magnitudes on the plate. Since the intensities (converted into relative magnitudes) define the slope of the magnitude-diameter relationship for the points on the trail, a marked divergence of these points from the magnitude-diameter relationship for the stars on the plate could be interpreted in the light of the effect to be expected from a meteor of finite angular size.

*If two sources are situated in a turbid medium (such as a photographic emulsion), in which Beer's Law is obeyed, and the brighter one moves in a straight line in such a way that the effective exposure times of the two are the same, a larger amount of energy will be received at some equidistant point from the moving source than from the stationary one; hence, in the case we are considering, the spreading of the image of the meteor trail should be greater than that of a star. However, Ross (*The Physics of the Developed Photographic Image*, pp. 101-2, Van Nostrand-Eastman Kodak Co., 1924) has compared the turbidity-spreading of the images of a slit and a circular hole and obtained the unexpected result that the rate of growth of the images with increasing exposure time is the same.

It was found, however, that it was very difficult, if not impossible, to obtain the necessary accuracy in the measurement of the diameters of the star images. This circumstance was due to two factors. The plate on which the trail occurred was the second one exposed on the evening following a very warm day, and the Crossley mirror had not yet reached a stable temperature. Accordingly, the star images were not sharp and round. This effect was accompanied in the regions away from the central part of the plate, by coma. Measures of diameter on such irregular images were very uncertain. These effects were well seen also on the trail itself, the edge away from the center of the plate appearing poorly defined in comparison with the other.

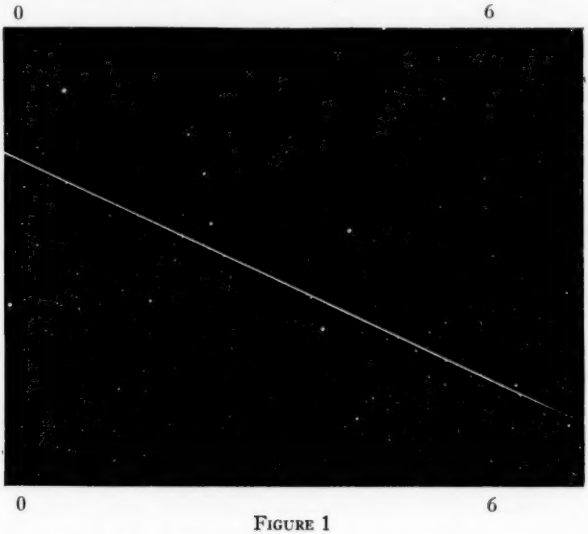

FIGURE 1

THE METEOR TRAIL ON A CROSSLEY REFLECTOR PLATE

The photograph includes the southern half of the original plate. The vertical rules "0" and "6" indicate the portions of the trail corresponding to the points so numbered on the horizontal scale of Figure 2. North is at the top of the photograph.

In order to determine whether any large effect was present, the diameters of the images of about 30 stars were measured and their square roots were plotted against the astrographic magnitudes, which themselves were determined originally by diameter measurements. The approximately linear relationship thus obtained was compared with the values from points on the trail not too distant from the center of the plate. The slope of the mean curve thru these points seemed to differ from that of the curve for the stars, in the sense that, as the meteor grew fainter, the effect to be expected from an appreciable angular diameter appeared. The scatter of the individual plotted points was so great, however, that no quantitative study was attempted. It should be recognized that, even if the definition of the plate had been satisfactory, the magnitudes of the astrographic plate, which were derived originally from those of the *Henry Draper Catalogue,*

would have borne close investigation to insure that no systematic scale effect had entered into the results. Probably the most satisfactory method of procedure would be to redetermine the magnitudes of selected stars with the Reflector; this would also avoid the difficulty of reconciling two different color systems.

It may be of interest, however, to reproduce here the measures of relative intensity along the trail, since they define the "light curve" of the meteor as it passed across the plate (Figure 2). Inasmuch as the Crossley plate was not provided with any sensitometric calibration, the "spot" calibrations of two spectrograms taken on the same emulsion (Eastman 103a-O) and of the same emulsion number were used. The calibration exposures were made in the Mills sensitometer, behind a Wratten 50 (blue) filter; the effective wavelength of the filter-

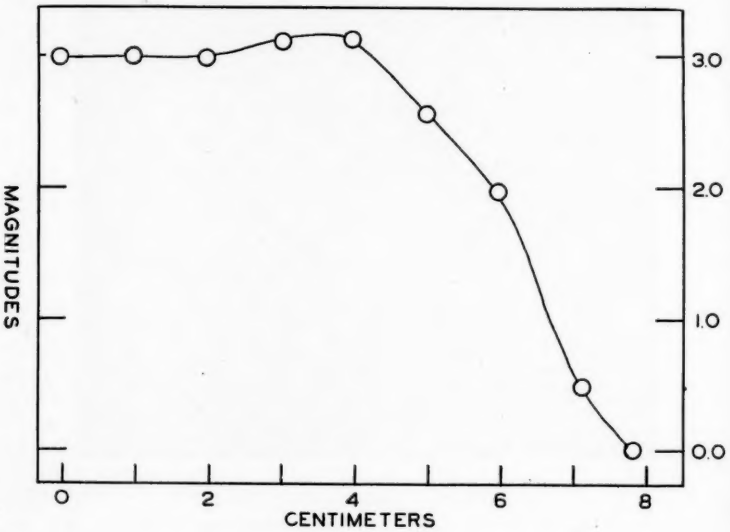

FIGURE 2

THE PHOTOGRAPHIC LIGHT CURVE OF THE METEOR

The horizontal scale represents distance along the trail, measured in centimeters; the vertical scale shows relative magnitudes of the trail, referred arbitrarily to the faintest point as zero.

plate combination is about 4600A. The developments of the calibration plates and the meteor plate were closely similar. The very low reciprocity-failure of the 103a-O emulsion makes it possible to apply characteristic curves obtained at the intensity level of the sensitometer (exposure 30 seconds) to the high-intensity level of the meteor trail (effective exposure a small fraction of a second). Tracings were run across the trail with the Moll recording microphotometer; the points selected for tracing were about a centimeter apart. Care was taken to avoid any superimposed star images. The galvanometer deflections were reduced to relative intensities by a mean, characteristic curve from the two sets of spots. The areas under these intensity curves and above background fog were then measured with a planimeter and converted into relative magnitudes. These results

are plotted in Figure 2, distances along the trail as abscissas and relative magnitudes as ordinates. Adopting the aforesaid criterion of direction of motion, we find that the meteor moved from left to right along the curve.

An Unusual Photograph of a Meteor

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ABSTRACT AND INTRODUCTION

As far as I am aware, the accompanying photograph (Figure 1), obtained on October 15, 1934, at Claremont, California, is the only picture of a meteor *trail* which seems to show evidence of a wind at a high altitude in the Earth's atmosphere, altho several pictures of meteor *trains** showing such evidence are in existence. The present photograph appears to be also the only picture exhibiting the meteorite within its gas cloud, unless the photograph secured by Charles M. Brown and reproduced as Figure 1 in *P. A.*, **42**, 291, 1934, and as Figure 3 in *C.S.R.M.*, **1**, No. 2, 38; *P. A.*, **44**, 387, 1936, should be counted. In that photograph, *two* bodies appear to be about to *emerge* from a gas cloud.

The important facts relating to this photograph (Figure 1) may be presented as follows:

(1) The photograph was made by me on October 15, 1934, near the Frank P. Brackett Observatory of Pomona College, at Claremont, California. A picture was being taken of star trails in the north polar region of the sky, and the meteor appeared at about 8:00 P.M., P.S.T.

(2) The camera used was a Voigtländer Avus, equipped with a Skopar *f*. 4.5 lens of 13.5 cm. focal length. My records do not show precisely what kind of film was used, but it was almost certainly one of the faster grades of Eastman panchromatic, with antihalation backing.

(3) The meteor was very bright and of a pure white color. It flickered irregularly and ended in a final burst. No sounds were heard. The image of the trail lies nearly in the center of the field. It begins almost at the Pole Star and extends 2.5 cm. in a downward direction 33° from the vertical, toward the east. No luminous train was observed.

FIGURE 1
THE METEOR PHOTOGRAPHED ON OCTOBER 15, 1934, AT CLAREMONT, CALIFORNIA

(4) Two phenomena can be noted which seem to be sufficiently unusual to be worth reporting. The flickers detected visually are recorded as a series of more than a dozen bursts of varying intensity. All but the last are approximately in the middle third of the trail. The unusual thing about them is that a line drawn along the trail, thru the parts free from bursts, does not pass thru the

*Regarding the distinction between "Meteor Trails and Meteor Trains," see F. C. Leonard, *C.S.R.M.*, **2**, 84; *P. A.*, **47**, 102, 1939.

center of any burst; it is as tho the "flame" of the falling meteorite had been blown toward the east by a powerful wind.

(5) The effect detailed in the preceding paragraph is most marked in the final burst at the end of the trail. Of greater interest is the fact that within the egg-shaped burst and in a direct line with the burst-free parts of the trail is an especially bright spot. The light area around this spot does not have the appearance of halation (I have compared it with photographs taken with the same camera, of illuminated pin-holes, some of which *do* show halation). Moreover, unlike halation, it is not symmetrical about the spot, but extends at least 3 times as far in a direction upward and to the east as it does in the opposite direction. In my opinion, the bright spot is the image of the *incandescent meteorite*. The cloud around the spot may be incandescent gas or dust emitted by the burst, altho the sharpness of its image disfavors this hypothesis. Whatever its nature, it has been materially displaced by some agency, perhaps a wind.

(6) In addition to the main bright spot, there are 3 or 4 other spots just barely brighter than the background and located near the edge of the "gas cloud." I think that these may be images of fragments thrown off from the main mass in the course of the bursting process.

(7) A wind has just been suggested as the cause of the asymmetry of the meteor trail. Commenting on this explanation, Mr. George H. Herbig of the Lick Observatory writes, in a private letter: "Measurement of the print and reasonable assumptions as to the enlargement and the height and duration of incandescence (0.5 second) of the meteor, *etc.*, lead to an apparent wind velocity of about 100 miles per hour, which value may be more or less correct, depending upon projection effects."† It is true also, as he comments, that the effect may be due possibly to some optical cause. However, nothing of the kind has ever been photographed with this camera; the star images show nothing like it even at the edges of the film; and none of the pin-hole photographs mentioned previously exhibits any asymmetry of any kind. Therefore, I am of the opinion that the effect is real.

†This quotation should not be taken to mean that Mr. Herbig *endorses* the wind hypothesis. He describes himself as being "a neutral, or perhaps slightly skeptical, bystander" as regards the matter.

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus 10

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, P. O. Box 9866, Los Feliz Station, Los Angeles 27, California

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

AAVSO Meeting: The 33rd Annual meeting of the AAVSO was held at the Harvard Observatory on Friday and Saturday, October 6 and 7, 1944. The Friday session started with the council meeting at 4:00 P.M., with a very representative attendance, preceded by an informal tea. Ten new members were admitted to annual membership, besides two of life membership. These, with

those elected by mail vote of the Council in May, make a total of thirteen annual and four life members for the year.

After much discussion, the appointment of a solar observation committee, under the chairmanship of Mr. Neal J. Heines of Paterson, New Jersey, was approved. The selection of a committee was also authorized to study a possible revision of the constitution and by-laws to bring them up-to-date. The extension of the life of the Auroral Committee to another three years was also voted upon favorably. The Council also authorized the reprinting of the Circular of Instructions and the printing of the Secretary's Index to Volumes I, II, and III of Variable Comments.

The Friday evening session was held with the Association attending the annual meeting of the Bond Astronomical Club as its guests. This meeting marked the 20th anniversary of the founding of the Club and, following a brief business session, the program consisted of remarks and addresses by past presidents recounting the various aims, activities, and accomplishments of the Club. The general consensus was that the Club had well justified not only its foundation, but its continued existence.

On Saturday morning the Association met for its regular business session, with about fifty persons present. Reports of Committees were received and discussed, also the 13th Annual Report of the Recorder. One of the most active committees of this Association is that on occultations, reported on by Dr. Farnsworth as chairman. The work, not only of obtaining the necessary observations but also of making the reductions, has gone on apace. For example, in 1941, 36 occultations were observed, 49 in 1942, 58 in 1943, and 41 thus far in 1944. Principal observers in this program have been Messrs. Sill of Mamaroneck, New York; Monnig of Fort Worth, Texas; Halbach and Wade of Milwaukee, Wisconsin; and groups of observers in Cincinnati, Ohio, and in Texas. Principal computers have been Messrs. Cooke of Joliet, Illinois, Packard of Newton, Massachusetts, Griswold of Hartford, Connecticut, and Miss Young, now of Claremont, California.

The Recorder's report indicated a healthy condition, especially as regards variable stars, observed and discussed. A total of 32,767 observations were communicated by 70 observers. This number exceeds by almost 1500 the total for 1943. Twenty-three persons contributed reports for each month, with an average of 100 estimates per month on 60 stars by each observer. Heading the list again this year is Fernald, of Wilton, Maine, with 5316 to his credit, or an average of 443 observations on 204 variables per month. Mr. de Kock of Cape Town, South Africa, followed with 2878 estimates, Rosebrugh made 1617 estimates, Peltier, 2215; Meek of Glendale, California, 1606; Hartmann of St. Albans, New York, 1578; Nadeau of Quebec, Canada, 1337; Holt, 1258; Mrs. Kearons, now of West Bridgewater, Massachusetts, 1152; Cousins of Durban, South Africa, 1057; and Sill, 1029.

From South Africa came a total of 3976 estimates by three observers; from Canada, 2381 by six observers; South America, 1030 by two; Australia, 294 by two; India, 580 by two; and Mexico, 271 by one observer. The sixteen foreign observers contributed 8532 observations, and our forty-four American observers sent in 24,235, or 74 per cent of the whole.

The McAteer Library was augmented by 198 acquisitions, including 35 volumes. Telescopes have been loaned to Messrs. S. A. Parks of Fall River, Massachusetts, and Donald Mary, of Baton Rouge, Louisiana.

The Association has issued, besides the Bi-Monthly Bulletins, two numbers of Variable Comments; Nos. 5 and 6 of *Harvard Annals* 110 containing the observations of nearly 500 variable stars. Nos. 7 and 8 of the same volume, bringing the published observations to the end of 1942, are in the hands of the printer. *Harvard Annals* 114, Part I, containing the observed dates of Maxima and Minima of 387 Long-Period Variables, for the years 1921-41, is practically ready for printing, and Part 2, a discussion of the light curves of these same long-period variables, is well on the way to typing.

The surprise of the morning—to the Recorder at least—was the presentation to him of the Eighth Merit Award of the Association, beautifully illuminated by Mr. Fred E. Jones, and suitably framed.

The election of Council members resulted in the addition to its membership of Mrs. Helen S. Federer, and Messrs. H. M. Harris of South Portland, Maine; S. A. Parks of Fall River, Massachusetts; and E. A. Sill of Mamaroneck, New York. Later the Council, as newly constituted, elected the following officers for the ensuing year: President, Roy A. Seely of New York, N. Y.; First Vice President, Charles H. Smiley of Brown University; Second Vice President, Marjorie Williams of Smith College; Secretary, D. W. Rosebrugh; Treasurer, P. W. Witherell; and Recorder, Leon Campbell.

The afternoon session was given over to the presentation of papers. Mr. Heines described in detail the methods of observing and recording sun-spots; Mr. Harris described the adjustment of his sidereal clock; Mr. Rosebrugh explained the use of finders as necessary accessories to any telescope; and Dr. S. Gaposchkin spoke on Elusive Stellar Radii, in which he showed that some giant eclipsing variables are surrounded by thick atmospheres, similar in this respect to long-period variables for which greatly extended atmospheres are probable.

For the perusal of the members seated about "Hollow Square" tables, the Recorder had on display numerous plots of observations of currently interesting variables, both Long-Periods and Irregulars.

Tea was served later in the afternoon by the Observatory staff, an occasion which gave the members an opportunity to discuss their favorite variable star problems.

At 7:00 o'clock that evening 60 members and guests sat down to dinner at the Harvard Faculty Club. When the gastronomical feature of the evening had been concluded, we listened to addresses from several members and guests.

The secretary described his work in connection with the preparation of his Index to Variable Comments, adding a few side lights on what he had unearthed in his perusals. Dr. James G. Baker gave us a very clear explanation of the Matsukov type of reflector, and Mr. Harris told us of the activities of the Maine Astronomical Society. Incidentally, there were present a full dozen members of this group.

Dr. Shapley followed with his annual Highlights. These were (not necessarily in order of importance):—

1. The Oterma object—Comet or Asteroid?

2. The discovery of an atmosphere on Titan containing methane and ammonia, substances already found in Saturn's atmosphere.

3. The 1944 Solar Eclipse Expedition to Peru by the Mexican Astronomers.

4. Analysis of the orbit of Mercury, leading to the new determination of

the advance of its perihelion, and indirectly to an idea of the rate of advance of the Earth's perihelion.

5. Photographing of "spicules" on the sun at Climax, Colorado.

6. Frequency of double stars; now five out of six, as against two out of three, as previously supposed.

7. The discovery of an exceedingly faint companion to the star BD + 4°4048, at a distance of 440 astronomical units, with an absolute magnitude of 19 in red light.

8. The detection of more stars having deep envelopes similar to that about Beta Lyrae.

9. Redetermination of distances of globular clusters; some brought closer, others unchanged.

10. Resolution of nucleus of Andromeda nebula and its companions into actual stars.

The meeting came to a close with an appropriate vote of thanks to the Observatory staff for the part it had played in making the meeting so successful and memorable. It was the expressed hope that in 1945 a still larger meeting might be held in October, with the possibility of the resumption of the spring meetings next May, depending on war and travel conditions.

Observations for September, 1944: A total of 3971 observations was contributed by 41 observers during the month of September, as listed herewith:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Bappu	35	74	Kelly	9	14
Blunck	49	49	de Kock	68	232
Boone	30	30	Koons	41	102
Bouton	22	33	Luft	9	77
Buckstaff	20	52	Mary	54	75
Chandra	82	86	Nadeau	113	114
Cousins	45	95	Oheim	71	174
Dafter	9	51	Oravec	7	20
Duffie	27	61	Parker	31	31
Fernald	283	866	Parks	31	54
Ford	31	32	Peltier	151	229
Garneau	51	58	Reeves	3	4
Guimont	10	22	Renner	14	18
Halbach	10	11	Rosebrugh	28	393
Harris	51	82	Schoenke	20	32
Hartmann	146	167	Sill	181	184
Holt	88	112	Treadwell	11	20
Houston	31	60	Webb	32	33
Howarth	11	11	Weber	94	94
Huffer	20	33	Weitzenhoffer	6	19
Kearons	66	67			
			41 (Totals)		3971

October 12, 1944.

Comet Notes

By G. VAN BIESBROECK

Comet Berry—News of the discovery of an unexpected comet visible to the naked eye in the southern hemisphere was received in this country on September 20 through the Carter Observatory, Wellington, New Zealand. The discoverer, D. C. Berry, Dunedin, N. Z., director of the comet section of the New Zealand

branch of the British Astronomical Association, communicated the following data:

1944 September 13 at $8^h\ 15^m$ Universal Time
Right ascension $7^h\ 40^m$ Daily variation $+22^m$
Declination $-75°\ 0'$ Daily variation $+3°\ 12'$
Magnitude 5—Tail less than one degree in length.

The rapid motion almost certainly indicates close proximity to the earth. However, nothing can be concluded yet about the future course of the comet, especially about the chances of visibility on this side of the equator, until further observations become available. This comet will probably receive the provisional designation as 1944 *e* in order of discovery but in view of the difficult communications at the present time it is best to wait until it is certain that no other comets have been found previously somewhere else.

Comet 1944 *c* (du Toit) for which improved elements were given on p. 415 of the last month's issue has now been recorded photographically by the writer on September 26 as an extemely diffuse and faint nebulosity close to the ephemeris position. The magnitude was estimated at 17 and since the comet is receding it will not be seen much longer.

The only other comet now under observation is Periodic Comet Schwassmann-Wachmann I which continues to fluctuate considerably in appearance. Almost stellar on September 22, it was diffuse and little condensed on September 26 and 29 but remained as faint as magnitude 15.

Williams Bay, Wisconsin, October 10, 1944.

General Notes

Dr. S. A. Mitchell is continuing to serve as Professor of Astronomy at the University of Virginia and Director of the Leander McCormick Observatory. During the past summer he was in residence at the Mt. Wilson Observatory engaged in photographing with the 60-inch reflector the spectra of faint stars for which trigonometric parallaxes have been determined at the McCormick Observatory.

On May 11 of this year, at the conclusion of 30 years of distinguished service by Professor Mitchell to the University of Virginia, a committee of his colleagues arranged an album of 146 testimonial letters and presented it to Professor Mitchell. His many friends throughout the United States, Canada, and abroad were pleased to have a part in this commemoration.

Professor Mitchell is to be congratulated upon his mental and physical vigor which enables him after so long a period of service to continue actively in his accustomed duties.

How Bombs May Affect Weather*

When a flying bomb was exploded in the air by our defences over Southern England recently, barometric pressure showed a sudden rise of about one-tenth, and then a return to the previous steady level.

The barometer was a few hundred yards to the left of the explosion, which probably took place between 2000 and 3000 ft. up.

*From the *London Evening Standard*.

Pressure waves of this kind may, under favorable conditions, produce slight weather abnormalities locally. Raindrops from a shower cloud, would be arrested in their fall and carried upward again, the ultimate fall being much heavier over a limited area than would have occurred in normal circumstances.

Violent explosions at cloud level could cause very slight local rainfall by furnishing through the small explosive particles, numerous nuclei of condensation, or by causing myriads of cloud particles to coalesce. Clouds, already forming, might be speeded up in the process by convectional currents set up around the core of the explosion.

These local effects would occur only when the weather and clouds were favorable. The explosions could not, in any circumstances, produce rain during dry, settled weather, or cause widespread cloud formation during weather unfavorable to cloud development.

Large quantities of dust in the atmosphere, due to widespread and frequent explosions, may produce vivid sunset colors and lead to faintly colored haloes around the sun and moon.

Book Review

Astronomy, Introductory, by J. B. Sidgwick. (Philosophical Library, New York City. $2.50.)

In this book the author uses the first 70 pages for a description of the several classes of celestial objects and their phenomena. One finds here a brief introduction to the material which the science of astronomy deals with. A familiarity with these pages should enable any one to interpret intelligently the aspect of the sky at night.

The second part, about the same number of pages, is given to a study of the constellations. In addition to the usual charts of the sky for different seasons, 47 of the constellations are depicted separately. They are in alphabetical order and hence readily found. A novel and convenient device is a scale which defines the size of the constellation in question. Also the objects of special interest in each constellation are named and described. The bordering constellations are indicated by name. The last two pages contain a glossary of terms and abbreviations. All of these features will be most helpful to the beginner in the study of the stars. C.H.G.

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